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Studies on the zeolites. Part VIII. A theory of the vapour pressure of the zeolites, and of the diffusion of water or gases in a zeolite crystal.[1]

By Max H. Hey, M.A., B.Sc.
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[Read June 7, 1934.]

THE behaviour of the zeolites on dehydration, and their capacity for absorbing other gases and vapours in place of the water moved, have formed the subject of numerous investigations, quali- tive and quantitative, of various degrees of accuracy. In only a w cases have attempts been made to fit an equation[2] to the perimental data. Of these equations, those proposed by O. Weigel, F. Hüttig, and O. Schmidt[3] are quite inadequate, as is readily en by a trial with the more extensive data now available. On the her hand, E. Rabinowitsch[4] derived an equation which proved pable of reproducing the experimental data and is very similar to e equation now proposed, but derived in a quite different way.[5]

[1] Parts I–VII, Min. Mag., 1930–1934, vols. 22–23.

[2] Other than a Freundlich isotherm, an empirical type of equation which ll almost always represent the data over a limited range.

[3] O. Weigel, Sitzungsber. Gesell. Naturwiss. Marburg, 1924, p. 107 [M.A. 373]; G. F. Hüttig, Fortschr. Chem. Phys. und Physikal. Chem., 1924, l. 18, no. 1, and Kolloid-Zeits., 1924, vol. 35, p. 337 [M.A. 5–82]; O. Schmidt, its. Physikal. Chem., 1928, vol. 133, p. 263 [M.A. 5–81].

[4] E. Rabinowitsch, Zeits. Physikal. Chem., Abt. B, 1932, vol. 16, p. 50 [M.A. 355].

[5] The similarity is not immediately apparent, but is readily disclosed by bstituting $(1-x)$ for Q/Q_m and writing the equation logarithmically.

Rabinowitsch's equation is not, however, perfectly satisfactory, as it is found impossible, on applying it to the newer experimental data, to uphold either of the interpretations he suggests for the constant b.

The equation now proposed is based on the assumption that the water in the zeolites occupies a definite integral number of lattice positions per unit cell, which need not all be filled; the water is, however, readily mobile, since the binding energy in the lattice is not very large. The grounds on which it is held that such a view best represents the condition of the water in the zeolites will be discussed below.

The theory here developed applies not only to the zeolites, but to any crystalline compound of a volatile and non-volatile component the crystal-structure of which is such that the whole or a part of the volatile component can be removed without the structure collapsing. At present there is no comprehensive term for such compounds, and they are often referred to as 'zeolitic' compounds, after the best-known examples of the class, but a more satisfactory term is desirable. Although in most of what follows only zeolites or 'zeolitic' hydrates are referred to, it should be emphasized that the arguments and equations apply equally to all 'zeolitic' compounds, including, for example, the systems FeS–S, FeO–O_2, Pd–H_2, &c.

Theoretical.

For a primary treatment, it will be assumed that the volatile component does not undergo any change in molecular complexity (e.g. dissociation) in passing from crystal to vapour or the reverse; and that in the crystal all the molecules (or atoms) of the volatile component are structurally of the same kind, occupying one set of equivalent positions.

Consider a plate of the zeolite so cut and mounted that the free surface exposed to the vapour is of unit area, and is normal to the channels along which the water migrates, and which form so notable a feature of the structure of the zeolites. When the zeolite is partially dehydrated, let x be the fraction of water molecules that have been removed.

If p is the pressure of water vapour above the crystal, the number of water molecules striking the surface in unit time is $Np/\sqrt{2\pi MRT}$, where N is the Avogadro number, M the molecular weight of the volatile component (water), R the gas constant, and T the absolute temperature. But only a part of the surface of the

rstal consists of vacant lattice positions in which the water might ndense; if there are ν lattice positions for water per sq. cm. in the face layer,[1] the number of vacancies will be νx. Further, in order condense in a given vacant position, a water molecule must strike proper channel centrally, within a limited area a. For a spherical lecule of radius ρ entering a channel of effective radius r the area ll be $a = \pi(r-\rho)^2$. For a non-spherical molecule it is probably rmissible to use a mean radius unless one or more dimensions of entrant molecule exceed the diameter of the channel; in the ter case the expression for a will be complex, involving an entation factor. Lastly, it may be necessary for the incident lecule to possess a component of kinetic energy normal to the rstal surface greater than some value η (the activation energy of ndensation) if it is to condense. Of the incident molecules, only a ction $a x \nu$ per sq. cm. will strike vacant lattice positions within the ndensation area', a, and only a fraction $e^{-N\eta/RT}$ of these will have requisite activation energy η. Hence the number of water mole-es condensing in unit time will be $a x \nu N p e^{-N\eta/RT}/\sqrt{2\pi MRT}$.

Of the $\nu(1-x)$ water molecules in the surface layer, only a fraction $e^{-N\epsilon/RT}$, having a component of kinetic energy normal to the face greater than ϵ (the activation energy of evaporation), will ve sufficient energy to overcome the forces holding them to the tice; and only half of these will be moving in the right direction any moment. In an equilibrium state, the number of molecules aping is balanced by those condensing, and it is therefore permis-le to determine the number of molecules escaping in unit time by iding the number in a position to escape at any instant by the erage time required for escape.

The existence of an activation energy of condensation, η, implies a tential hump between the free vapour and the potential trough cor-ponding to the structural water lattice position.[2] Let the distance m the summit of the potential hump to the lattice position be $\frac{1}{2}D$, l from the hump to a point at which the escaping (or entering) lecule may just be regarded as free $\frac{1}{2}D'$. The distance $\frac{1}{2}D$ will be

[1] It is not necessary to consider more than the surface layer, since, in equili-um, the influence of deeper layers on condensation and on evaporation must essarily balance.

[2] That is, a molecule approaching a given vacant lattice position is at first elled, and only on reaching a certain point (which it will not reach, against repulsion, unless it has the necessary energy η) is it attracted into the tice position.

approximately equal to half the distance between equivalent water lattice positions, along the channels. Provided $N\epsilon/RT$ is large, which will normally be the case, the great majority of the escaping molecules will have energies but little greater than ϵ, and hence their mean velocity as they leave the lattice positions may be taken [1] as $\sqrt{2N\epsilon/M}$; this velocity is all lost as the summit of the potential hump is reached, after which the repulsion accelerates them again, so that on reaching the free vapour state their mean velocity is $\sqrt{2N\eta/M}$. Nothing is known of the law governing the acceleration and deceleration of the molecules, but as an approximation the time of escape may be taken to be χ times the value calculated on the assumption that both portions ($\frac{1}{2}D$ and $\frac{1}{2}D'$) of the path of escape are traversed in simple harmonic motion; [2] the factor χ should be greater than 1, but numerically small, and it may also be allowed to correct for any difference between D and the distance between equivalent water lattice positions. The time of escape is then

$$\pi\chi D\sqrt{M}/4\sqrt{2N\epsilon}+\pi\chi D'\sqrt{M}/4\sqrt{2N\eta}.$$

To a first approximation, it is probably permissible to assume that $D':D::\eta:\epsilon$; and the error introduced by this assumption is the less since η is probably much less than ϵ. Substituting $D\eta/\epsilon$ for D', and approximating $(1+\sqrt{\eta/\epsilon})/\sqrt{\epsilon}=1/\sqrt{\epsilon-\eta}$, since $\epsilon\gg\eta$, the time of escape becomes $\pi\chi D\sqrt{M}/4\sqrt{2N(\epsilon-\eta)}$, and the number of molecules escaping in unit time is:

$$2\nu(1-x)\sqrt{2N(\epsilon-\eta)}\,.\,e^{-N\epsilon/RT}/\pi\chi D\sqrt{M}.$$

Equating the number of molecules escaping and condensing, the equilibrium equation is:

$$p=[4(1-x)\sqrt{NRT(\epsilon-\eta)}\,.\,e^{-N(\epsilon-\eta)/RT}]/aNDx\chi\sqrt{\pi},$$

or $\log_e p=$

$$\log_e 4\sqrt{NR(\epsilon-\eta)}/aND\chi\sqrt{\pi}+\tfrac{1}{2}\log_e T-\log_e x/(1-x)-N(\epsilon-\eta)/RT.$$

In this equation, all the quantities must be expressed in comparable units—p in dynes per sq. cm., R, ϵ, and η in ergs, a and D in cm. It is more convenient in practice to use common logarithms, to have p in mm. Hg, the energies in calories, and a and D in Å., and to replace the activation energy difference per molecule of water, $(\epsilon-\eta)$,

[1] Strictly, the mean velocity is $\sqrt{2N\epsilon/M}+e^{N\epsilon/RT}.\sqrt{\pi RT/2M}.\Phi(\sqrt{N\epsilon/RT})$, where Φ denotes the Gaussian error function. If $N\epsilon/RT$ is large, the second expression is negligible.

[2] Compare J. E. Lennard-Jones, Trans. Faraday Soc., 1932, vol. 18, p. 351, who concludes, in a very similar problem, that the factor χ can be neglected.

the difference per gram-mol., $E = N(\epsilon - \eta)$. The equation then comes:

$$\log p = C + \tfrac{1}{2}\log T - \log x/(1-x) - E(\log e)/RT,$$

here $C = 5{\cdot}22 + \log\sqrt{E}/aD\chi$.

The heat of hydration,[1] $Q_x = -R\partial\log_e p/\partial(1/T) = E + \tfrac{1}{2}RT$. The riation in Q_x with T is so small that when isohydric curves are otted in the form log p against $1/T$ they are reduced to straight nes within the experimental error; this is in agreement with all the perimental results.

So far the equation has only been derived for a very special case, d it remains to generalize it. It was assumed that the whole free rface of the zeolite was normal to one particular direction. Now η, a, and D certainly vary markedly with direction in the crystal, t, since neither the equilibrium pressure nor the heat of hydration n so vary, the difference $\epsilon - \eta = E/N$ and the product aD must be nstant. The equation is therefore independent of direction.

It was assumed that the volatile component did not undergo any ange in molecular complexity in vaporization. This is true when e volatile component is water, but in several systems the volatile mponent is incorporated in the crystal as atoms, while in the vapour ase it is present as polyatomic molecules. The systems PdH–H_2, S–S_2, and Sb_2O_{4-5}–O_2 are examples of such systems, and recent ork tends to show that they are fairly numerous, especially among lphides and selenides, though the range in composition of the solid ase may be fairly small. In such cases atomic oxygen, sulphur, ., in the crystal may probably be regarded as being in equilibrium ith the minute equilibrium fraction of dissociated molecules in the pour phase, and the total pressure may then be calculated with e aid of the dissociation equation of the volatile component.

Thirdly, it was assumed that the water molecules are all structurally the same kind. Among zeolites in particular this is rarely the case, e water occupying two, three, or more sets of lattice positions. In uilibrium, each set of water molecules can be considered indepen- ntly, and the water distributes itself among the several sets, each which will have its own value for E, and possibly for a also, in ch a way that the equilibrium pressure is the same for each t. If two sets of water molecules have very similar values for the

[1] That is, the heat evolved when one gram-mol. of water vapour combines th an infinite amount of zeolite of degree of dehydration x, exclusive of the ternal work involved.

constants E and a, water will be lost from both sets to much the same degree during dehydration, but if the constants differ markedly for the two sets but little water will be lost from one set of positions until the other set is almost empty. But it is characteristic of zeolitic hydrates (if the above equation is correct) that in the partially dehydrated compound no set of water positions will be completely full, nor any quite empty. Indeed, it is impossible for any set of equivalent positions to be quite fully occupied, even when the zeolite is in contact with liquid water, for this would require $p = \infty$. But very little water need be lost to bring the dissociation pressure of the zeolite below the vapour pressure of water—something of the order of 0·01 % will often suffice, so that the deficit will often be quite impossible of direct detection. When the loss of water is small, the relative accuracy with which it can be determined falls sharply, and vapour pressure observations in this region become of little value.

In many zeolite structures there are cavities which might be occupied by water molecules but are not. Presumably the heats of hydration for these groups of lattice positions would be so small that at all accessible water vapour pressures the positions must remain practically empty. It is possible that a small degree of occupation of such 'forbidden' positions may account for the slight excess of water often found in zeolites after exposure to nearly saturated atmospheres, which excess is usually attributed wholly to adsorption. And it is always possible that another volatile component might prove able to occupy these positions, though this is not likely to occur, as the affinity of a zeolite for water is generally greater than for any other vapour, except perhaps ammonia.

On applying the above equation to the experimental data, it is found that in many cases E varies markedly with x, and often C also varies with x to a greater extent than the variation of its constituent factor, $\log \sqrt{E}$, would account for. The variation in E may be formally recognized by replacing it by $E_0\{1+f(x)\}$, where E_0 is the value of E for $x = 0$, and $f(x)$ some unknown function of x; in practice $f(x)$ often proves to be approximately linear, and is invariably positive. The origin of this variation in E is fairly readily understood; as the water is removed, the whole distribution of affinity in the crystal is necessarily disturbed, and the more water is removed the more firmly bound is what remains, leading to an increase in E with increase of x, i.e. a positive value of $f(x)$.

The variation in C, in so far as it is not solely due to a variation

LE, is found to be always an increase with increase of x, and is most certainly to be attributed to lattice shrinkage.[1] As the water removed the lattice tends to shrink, particularly in directions rmal to the water-bearing channels; this shrinkage normally[2] creases the area of the channels, and hence the 'condensation ea', a. The variation in a may be formally expressed by writing $= a_0\{1+\phi(x)\}^2$, where a_0 is the value of a for $x = 0$; then taking $= \pi(r-\rho)^2$, as above, $\phi(x) = (r-r_0)/(r_0-\rho)$, so that if the lattice inkage and consequent decrease in r are linear functions of x, as often the case to a first approximation, $\phi(x) = -x(r_0-r_1)/(r_0-\rho)$. When the lattice shrinkage is very marked it often departs from linear approximation, and there sometimes seems to be a tendency the shrinkage to regulate itself so that the vapour pressure remains astant over a fairly wide range of x-values; such pseudo-univariant ilibria, exemplified by natrolite, the palladium-hydrogen system, l probably also by calcium sulphate hemihydrate, have hitherto ained unexplained.

Thus, eliminating all dependent variables,[3] the equation may be tten:

$$\log p = C_0 + \tfrac{1}{2}\log T - \log x/(1-x) - 2\log\{1+\phi(x)\} + \tfrac{1}{2}\log\{1+f(x)\} - E_0\{1+f(x)\}(\log e)/RT,$$

ere $C_0 = 5{\cdot}22 + \log\sqrt{E_0}/a_0 D\chi$.

The interpretation of the existing experimental data.

Edingtonite (figs. 1 and 2) shows fairly simple behaviour, and its pour pressure surface can be readily formulated if it is assumed at the water is divided between two groups of four equivalent sitions per unit cell each, which may be indicated conveniently by iting the unit cell formula: $Ba_2Al_4Si_6O_{20}.(4+4)H_2O$. This division the water into two groups is in agreement with the X-ray work of . H. Taylor and R. Jackson.[4] The X-ray work would also lead

[1] The reality of lattice shrinkage has been repeatedly demonstrated by X-ray d specific gravity measurements.

[2] In some types of structure (e.g. chabazite) lattice shrinkage does not pear to affect the water-bearing channels.

[3] Strictly, both E_0 and a probably vary slightly with temperature, but the riation is in general too small to be detected with the range of experimental nperatures normally available. The variation in D due to thermal expansion negligible.

[4] W. H. Taylor and R. Jackson, Zeits. Krist., 1933, vol. 86, p. 53 [M.A. 5–4].

one to expect that the two groups of water molecules will have appreciably different volatilities, since their surroundings in the crystal are different, and this is found to be the case. The more volatile group of water molecules have $E = 1{\cdot}35\,(1 + 0{\cdot}22x) \times 10^4$

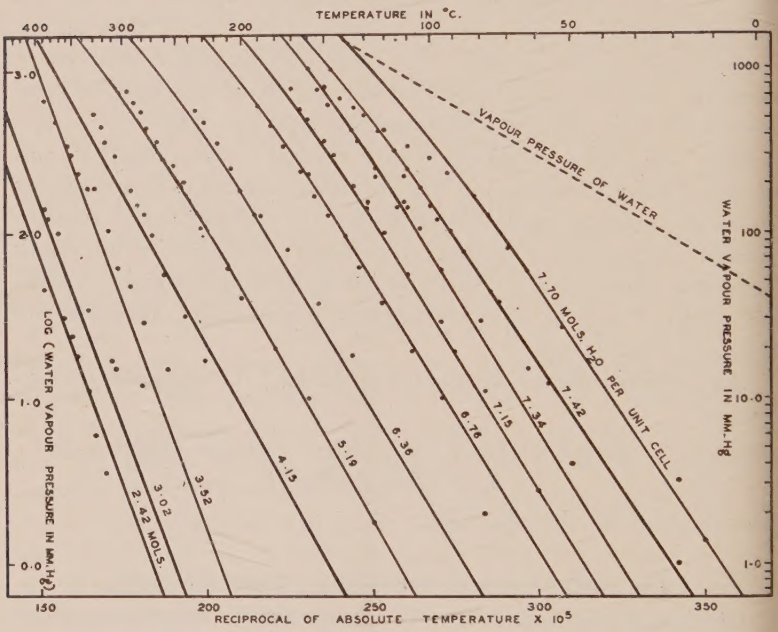


FIG. 1. Calculated isohydric curves for edingtonite, compared with the experimental data.

cals. per gram-mol. of water, and $C_g = 8{\cdot}34$. The experimental data are hardly sufficient to fix all the constants for the less volatile group of molecules with any certainty, but indicate that C_0 differs but little for the two groups. If it be assumed that the difference in C_0 for the two groups is equal to the difference in $\log \sqrt{E}$, then the less volatile group will have $C_0 = 8{\cdot}50$, and three values of E can be deduced, for as many values of x, which agree fairly well with the linear expression $E = 2{\cdot}35\,(1 + 0{\cdot}17x) \times 10^4$ cals. A slightly different assumption as to the value of C_0 will of course give slightly different values of E. The mean heat of hydration of edingtonite over the range 2·4 to 8·0 mols. water per unit cell, computed from the above expressions for E, is 18,000 cals. per gram-mol. of water at room-

emperature. The calorimetrically determined figure was 17,000 cals. The experimental vapour pressure data for edingtonite are given in able I, which also shows the agreement between the observed and alculated values of log p.

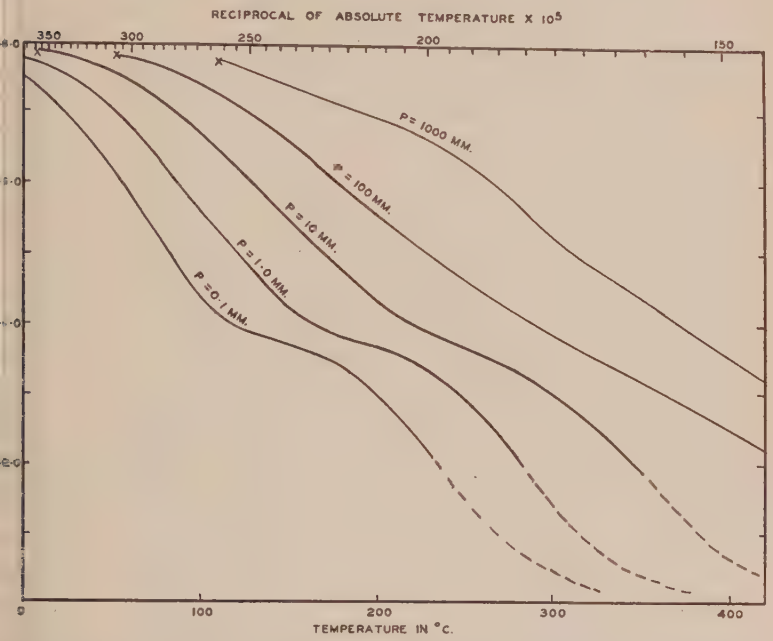


FIG. 2. Calculated isobaric dehydration curves for edingtonite. A typical example of subdivision of the water into two groups. In this and other isobaric graphs the curves terminate towards low temperatures at saturation points, where liquid water condenses.

Mesolite crystallizes in the space-group C_2^3, which has, in the face-centred aspect adopted, sets of four or eight equivalent positions in the unit cell. The water is almost certainly in general positions, and the unit cell formula may therefore be written

$$Ca_{16}Na_{16}Al_{48}Si_{72}O_{240}.(8\times 8)H_2O.$$

The task of working out vapour pressure constants for such a case would in general be almost impossible, but fortunately the relation of this zeolite to natrolite and scolecite assists. The formula amounts to one natrolite and two scolecite unit cells combined, and there is reason to believe that this represents the actual structure rather

TABLE I. Observed and calculated water vapour pressures of edingtonite from Böhlet, Sweden (B.M. 81049), for various water contents and temperatures.

Series 1. $c = 7{\cdot}70$ mol.
$x_1 = 0{\cdot}075$ to $0{\cdot}095$.
$x_2 = 4\times10^{-9}$ to 7×10^{-7}.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
19	0·49	0·38
53	1·41	1·45
64	1·76	1·75
71	1·90	1·93
77	2·10	2·12
83	2·22	2·21
92	2·33	2·43
100	2·45	2·58
109	2·53	2·73
119	2·63	2·90
130	2·70	3·04

Series 2. $c = 7{\cdot}42$ mol.
$x_1 = 0{\cdot}145$ to $0{\cdot}165$.
$x_2 = 10^{-8}$ to 10^{-6}.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
19	0·00	$\bar{1}$·92
57	1·08	1·10
74	1·58	1·56
92	2·00	2·00
97	2·08	2·12
104	2·27	2·28
110	2·39	2·40
116	2·50	2·52
123	2·62	2·68
135	2·76	2·85
142	2·82	2·97
140	2·88	3·06

Series 3. $c = 7{\cdot}34$ mol.
$x_1 = 0{\cdot}155$.
$x_2 = 10^{-7}$ to 10^{-6}.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
50	0·6	0·85
64	1·18	1·25
78	1·63	1·61
87	1·88	1·82
100	2·16	2·11
111	2·35	2·35

Series 4. $c = 7{\cdot}15$ mol.
$x_1 = 0{\cdot}21$ to $0{\cdot}23$.
$x_2 = 4\times10^{-7}$ to 3×10^{-6}.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
114	2·26	2·18
80	1·46	1·35
96	1·88	1·75
105	2·02	1·96
110	2·16	2·08
112	2·19	2·11
124	2·34	2·41
125	2·39	2·42
133	2·56	2·56
138	2·63	2·63
149	2·79	2·83
155	2·88	2·90

Series 5. $c = 6{\cdot}76$ mol.
$x_1 = 0{\cdot}31$ to $0{\cdot}33$.
$x_2 = 10^{-6}$ to 10^{-4}.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
128	2·18	2·12
79	1·04	0·98
90	1·28	1·27
95	1·46	1·41
120	2·00	1·96
129	2·16	2·12
134	2·28	2·26
146	2·48	2·45
150	2·56	2·53
160	2·71	2·66
163	2·75	2·72
170	2·88	2·81

Series 6. $c = 6{\cdot}36$ mol.
$x_1 = 0{\cdot}41$ to $0{\cdot}43$.
$x_2 = 2\times10^{-6}$ to 2×10^{-4}.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
160	2·36	2·34
94	1·0	1·00
80	0·3	0·62
108	1·28	1·33
122	1·57	1·63

TABLE I (*continued*).

Series 6 (*continued*).

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
134	1·79	1·87
141	1·98	2·00
148	2·11	2·16
156	2·23	2·28
165	2·38	2·41
175	2·53	2·57
183	2·66	2·69
191	2·78	2·81
199	2·88	2·97

Series 7. $c = 5{\cdot}39$ mol.
$x_1 = 0{\cdot}65$ to $0{\cdot}67$.
$x_2 = 5 \times 10^{-5}$ to 10^{-3}.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
192	2·20	2·12
137	1·26	1·14
154	1·57	1·48
172	1·90	1·79
187	2·11	2·05
199	2·26	2·26
207	2·40	2·36
219	2·56	2·53
228	2·68	2·63
235	2·76	2·73

Series 8. $c = 4{\cdot}72$ mol.
$x_1 = 0{\cdot}82$ to $0{\cdot}84$.
$x_2 = 5 \times 10^{-4}$ to $0{\cdot}01$.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
160	1·00	0·94
180	1·30	1·30
200	1·61	1·66
210	1·79	1·80
230	2·04	2·08
243	2·32	2·27
250	2·42	2·37
265	2·57	2·52
272	2·65	2·62
280	2·75	2·68
286	2·81	2·76
293	2·88	2·82

Series 9. $c = 4{\cdot}15$ mol.
$x_1 = 0{\cdot}93$.
$x_2 = 0{\cdot}03$ to $0{\cdot}04$.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
275	2·13	2·00
228	1·23	1·34
242	1·50	1·57
258	1·75	1·78
270	2·00	1·93
282	2·18	2·08
289	2·27	2·15
304	2·48	2·34
313	2·57	2·45
319	2·66	2·48
326	2·74	2·55

Series 10. $c = 3{\cdot}52$ mol.
$1 - x_1 = 0{\cdot}01$ to $0{\cdot}04$.
$x_2 = 0{\cdot}13$ to $0{\cdot}10$.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
328	2·28	2·00
255	1·18	0·82
276	1·46	1·20
290	1·68	1·40
301	1·79	1·61
313	2·02	1·80
335	2·20	2·10
343	2·37	2·28
352	2·48	2·38
357	2·54	2·43
372	2·69	2·63
385	2·82	2·80

Series 11. $c = 2{\cdot}82$ mol.
$1 - x_1 = 0{\cdot}001$ to $0{\cdot}01$.
$x_2 = 0{\cdot}30$ to $0{\cdot}31$.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
385	2·16	2·10
280	1·08 ?	0·47
306	1·18	0·94
310	1·23	1·00
335	1·54	1·40
370	2·01	1·88
380	2·10	2·04
390	2·16	2·15

TABLE I (*continued*).

Series 12. $c = 2{\cdot}42$. $1-x_1 = 4\times10^{-4}$ to 4×10^{-3}. $x_2 = 0{\cdot}40$.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
387	1·66	1·78
314	0·54	0·76
325	0·78	0·98

Series 12 (*continued*).

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
332	1·05	1·05
345	1·26	1·22
351	1·38	1·34
360	1·49	1·45

closely. Now scolecite, as will be shown later, has three groups of eight molecules each per unit cell, and one group is much more volatile than the other two,[1] which appear to have almost, if not quite, the same volatility. As a first trial, therefore, an attempt was made to interpret the mesolite data on an assumption of $16H_2O$ of high and equal volatility, and $48H_2O$ of lower and again equal volatility. This treatment proved fully satisfactory. The more volatile group of 16 water molecules was found to have $E = 2{\cdot}11\times10^4$ cals., and $C = 9{\cdot}17$. The constants for the less volatile group of 48 water molecules could not be fixed with the same degree of accuracy, but are near $E = 2{\cdot}52\times10^4$ cals. and $C = 8{\cdot}85$. The mean heat of hydration of mesolite over the range 33·7 to 64 mols. H_2O per unit cell, computed from the vapour pressure data, is 23,300 cals. per gram-mol. of water. Calorimetrically, a figure of 18,000 cals. was obtained, but it is quite possibly low. It was not shown that the whole of the water expelled was reabsorbed, and any failure to reabsorb part of it would lead to a low value for the heat of hydration. This explanation is supported by X-ray examination of a partially dehydrated mesolite containing about 30 mols. H_2O per unit cell, which showed considerable lattice breakdown.

The heats of hydration for the two groups of water molecules differ much less for mesolite than they do for edingtonite, and this is reflected in the isobaric curves, which show much less of a 'step' for mesolite than for edingtonite. While with edingtonite almost the whole of the more volatile group of water molecules can be removed before the less volatile ones begin to be removed to any appreciable extent, with mesolite, at 227° C. and 10 mm. Hg, when only 10·6 mols. H_2O have been lost from the more volatile group ($x = 0{\cdot}66$),

[1] More strictly, this applies to the high-temperature modification, metascolecite; scolecite itself has a more volatile group of 16 and a less volatile group of 8 molecules.

he loss of the less volatile group is already appreciable, being 0·8 nolecule ($x = 0{\cdot}016$). The observed and calculated values of log p or mesolite are shown in table II.

TABLE II. Observed and calculated water vapour pressures of mesolite from hore Ghaut, Syhadree Mts., Bombay (B.M. 33868), for various water contents nd temperatures.

Series 1. $c = 59{\cdot}8$ mols.*
$x_1 = 0{\cdot}26$.
$x_2 = 0{\cdot}001$ to $0{\cdot}006$.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
238	1·95	2·01
153	0·14	0·23
164	0·49	0·46
170	0·61	0·60
188	0·94	1·02
195	1·16	1·21
200	1·33	1·30
206	1·38	1·40
218	1·62	1·64
229	1·76	1·88
238	2·01	2·01
245	2·23	2·16
256	2·39	2·36
259	2·45	2·40

Series 2. $c = 57{\cdot}6$ mols.
$x_1 = 0{\cdot}40$ to $0{\cdot}38$.
$x_2 = 0{\cdot}002$ to $0{\cdot}008$.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
180	0·38	0·46
168	0·23	0·18
160	$\bar{1}$·78	0·00
170	0·00	0·23
180	0·23	0·46
200	0·83	0·93
200	1·03	0·93
210	1·21	1·12
222	1·32	1·36
235	1·62	1·60
254	2·01	1·94
264	2·12	2·12
277	2·27	2·30

Series 3. $c = 55{\cdot}1$ mols.
$x_1 = 0{\cdot}53$ to $0{\cdot}47$.
$x_2 = 0{\cdot}01$ to $0{\cdot}03$.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
291	2·41	2·32
298	2·50	2·42
312	2·60	2·68
320	2·70	2·78
332	2·80	2·93
334	2·89	2·99
344	2·95	3·13
352	3·04	3·23
330	2·94	2·93
324	2·89	2·83
315	2·85′	2·72
313	2·76	2·71
299	2·56	2·50

Series 4. $c = 53{\cdot}2$ mols.
$x_1 = 0{\cdot}65$ to $0{\cdot}56$.
$x_2 = 0{\cdot}01$ to $0{\cdot}04$.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
297	2·16	2·22
300	2·27	2·30
314	2·42	2·53
326	2·55	2·68
333	2·67	2·78
346	2·87	2·95
355	2·94	3·11
361	2·99	3·10
366	3·04	3·20
370	3·08	3·24
210	0·62	0·64
195	0·38	0·35
221	0·88	0·84
233	1·00	1·10
240	1·16	1·25

* There is some uncertainty as to this water content.

TABLE II (*continued*).

Series 4 (*continued*).

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
268	1·71	1·77
242	1·23	1·31
246	1·36	1·36
266	1·77	1·72
279	2·04	1·97

Series 5. $c = 52{\cdot}2$ mols.
$x_1 = 0{\cdot}68$ to $0{\cdot}63$.
$x_2 = 0{\cdot}02$ to $0{\cdot}04$.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
215	0·00 ?	0·64
220	0·46 ?	0·74
233	0·94	1·00
245	1·24	1·25
249	1·38	1·36
259	1·56	1·52
280	1·90	1·88
294	2·06	2·08
310	2·41	2·34
324	2·54	2·55
340	2·72	2·80
358	2·94	3·06
369	3·03	3·19

Series 6. $c = 47{\cdot}5$ mols.
$x_1 = 0{\cdot}88$ to $0{\cdot}79$.
$x_2 = 0{\cdot}05$ to $0{\cdot}08$.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
224	0·23	0·32
237	0·69 ?	0·60
270	1·28	1·24
279	1·34	1·40
299	1·70	1·72
315	1·99	2·00
255	0·95	0·97
292	1·50	1·62
310	1·81	1·90
331	2·28	2·22
352	2·45	2·55
361	2·65	2·66
380	2·86	2·93
382	2·90	2·90

Series 6 (*continued*).

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
386	2·95	2·99
395	2·99	3·09
352	2·54	2·55
320	2·42 ?	2·06

Series 7. $c = 41{\cdot}1$ mols.
$x_1 = 0{\cdot}96$ to $0{\cdot}89$.
$x_2 = 0{\cdot}15$ to $0{\cdot}18$.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
328	1·79	2·04
240	0·30	0·21
255	0·61	0·55
280	1·28	1·00
300	1·72 ?	1·32
300	1·62 ?	1·32
295	1·56 ?	1·22
315	1·79	1·62
340	2·17	2·01
371	2·63	2·46
385	2·72	2·58
398	2·88	2·74

Series 8. $c = 36{\cdot}1$ mols.
$1 - x_1 = 0{\cdot}07$ to $0{\cdot}03$.
$x_2 = 0{\cdot}25$ to $0{\cdot}26$.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
285	0·95	0·80
319	1·56	1·44
344	1·98	1·84
356	2·13	2·02
287	0·83	0·81
270	0·60	0·59
307	1·48	1·24
344	1·95	1·84
331	1·84 ?	1·60
360	2·13	2·08
365	2·21	2·12
376	2·35	2·31
387	2·45	2·43
401	2·60	2·59

TABLE II (*continued*).

Series 9. $c = 32{\cdot}5$ mols.
$1-x_1 = 0{\cdot}03$ to $0{\cdot}05$.
$x_2 = 0{\cdot}33$ to $0{\cdot}34$.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
290	0·23 ?	0·74
295	0·70	0·80
311	0·86 ?	1·14
325	1·20	1·32
352	1·59	1·79
376	1·93	2·13
380	2·00	2·19
391	2·16	2·30

Series 10. $c = 30{\cdot}7$ mols.
$1-x_1 = 0{\cdot}04$ to $0{\cdot}02$.
$x_2 = 0{\cdot}35$.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
328	0·42 ?	1·30
340	0·86 ?	1·54
346	1·32	1·60
338	1·32	1·48
370	1·80	2·00
346	1·49	1·60
378	1·97	2·08
395	2·22	2·28

Series 11. $c = 25{\cdot}6$ mols.
$1-x_1 = 0{\cdot}02$ to $0{\cdot}03$.
$x_2 = 0{\cdot}48$.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
336	0·64 ?	1·30
350	0·95 ?	1·46
360	1·23 ?	1·65
373	1·53	1·82
395	1·81	2·05
345	1·16	1·42
321	1·07	1·01
340	1·32	1·36

Series 12. $c = 23{\cdot}0$ mols.
$1-x_1 = 0{\cdot}01$ to $0{\cdot}02$.
$x_2 = 0{\cdot}52$.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
290	$\bar{1}$·3 ?	0·4
325	0·23 ?	0·96
336	0·70 ?	1·20
330	0·48 ?	1·07
380	1·52	1·82
351	1·15	1·42
380	1·54	1·82
401	1·78	2·05
358	1·43	1·54

Series 13. $c = 16{\cdot}0$ mols.
$1-x_1 = 0{\cdot}006$ to $0{\cdot}013$.
$x_2 = 0{\cdot}66$.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
390	1·23 ?	1·70
338	0·26 ?	1·01
353	1·02	1·24
357	1·34	1·42
385	1·61	1·64
390	1·84	1·90

Series 14. $c = 9{\cdot}7$ mols.
$1-x_1 = 0{\cdot}003$ to $0{\cdot}008$.
$x_2 = 0{\cdot}80$.

$t°$ C.	Log p (mm. Hg) Obs.	Calc.
290	$\bar{1}$·58	$\bar{1}$·90
316	0·00	0·38
350	0·64	0·88
377	1·04	1·32
392	1·28	1·48
399	1·46	1·58

Natrolite (fig. 3) also crystallizes in space-group C_2^3, and in the e-centred aspect has a unit cell formula $Na_{16}Al_{16}Si_{24}O_{80}.(8+8)H_2O$, th the water in two sets of eightfold positions. But there is an remely close approximation of the related space-group C_{2v}^{19}; if the ce-group were truly C_{2v}^{19}, the water would all be in one set of 16

equivalent positions. Hence it is not surprising that no difference in volatility could be detected between the two groups of water molecules. However, the behaviour is by no means simple. As X-ray work showed, dehydration results in a small degree of lattice shrinkage; as the condensation area, a, is already small in fully hydrated natrolite, a small shrinkage produces a relatively large decrease in a, and consequently the shrinkage factor $\log\{1+\phi(x)\}$ is very considerable. If the decrease in the channel radius, r, is assumed linear to x, the constant $(r_0-r_1)/(r_0-\rho)$ is found by a process of trial and error to be approximately 0·90. Then $C_0 = 8{\cdot}63$, while E is not even approximately linear to x; assuming the above values of the other constants, E may be calculated for each series of experimental data. These 'observed' values of E (table III) are plotted,

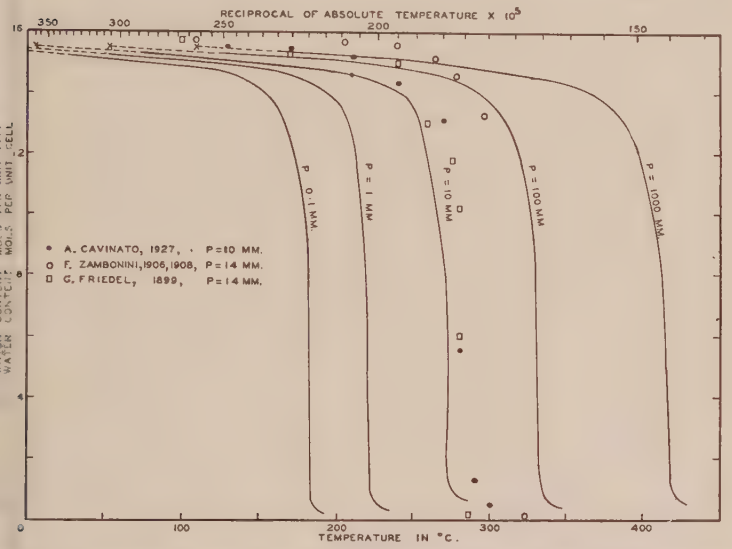
TABLE III. 'Observed' values of E for natrolite derived directly from the vapour pressure data, for various degrees of dehydration, and 'calculated' values taken from a smoothed curve.

Dehydration fraction, x.	$E\times10^{-4}$, cals. Obs.	Calc.	Dehydration fraction, x.	$E\times10^{-4}$, cals. Obs.	Calc.
0·044 ...	1·70	1·70	0·125 ...	2·34	2·34
0·044 ...	1·75		0·125 ...	2·37	
0·048 ...	2·22	1·78	0·14 ...	2·37	2·35
0·050 ...	1·99	1·83	0·14 ...	2·39	
0·052 ...	1·78	1·86	0·155 ...	2·38	2·36
0·052 ...	1·86		0·155 ...	2·44	
0·058 ...	1·96	1·96	0·21 ...	2·44	2·36
0·058 ...	2·05		0·21 ...	2·49	
0·062 ...	2·07	2·02	0·50 ...	2·36	2·36
0·069 ...	2·24	2·09	0·88 ...	2·43	2·36
0·071 ...	2·27	2·11	0·88 ...	2·25	
0·11 ...	2·32	2·31	0·95 ...	2·23	2·36
0·11 ...	2·35		0·95 ...	2·47	
0·11 ...	2·40				
0·11 ...	2·43				

a smooth curve laid through them, and 'calculated' values of E taken from this. From these constants, calculated values of $\log p$ are then obtained. The agreement between the experimental and calculated values of $\log p$ is relatively poor (the difference averages 0·4) for water contents above 15 mols. per unit cell ($x<0{\cdot}07$), owing mainly to the unavoidable inaccuracies in the determination of x, which increase the smaller x is. For water contents below 15 mols. per unit cell, $\log p_{\text{obs.}}\sim\log p_{\text{calc.}}$ averages 0·22. Space does not permit of a detailed comparison of the observed and calculated values, either graphically or in tabular form.

The above vapour pressure constants for natrolite cannot be re-
arded as final. The assumption of a linear form for $\phi(x)$ is probably
correct, and it is certain that, with more extensive data, much
etter agreement and more satisfactory vapour pressure constants
ould be obtained.

The mean heat of hydration of natrolite, estimated from the vapour



g. 3. Calculated isobaric dehydration curves for natrolite. An example of pseudo-univariant behaviour due to lattice shrinkage.

essure data, is 23,300 cals., while a figure of 22,800 cals. was found
lorimetrically.

The apparent step in the isobaric and isothermal dehydration
rves of natrolite is seen to be due, in all probability, to lattice
rinkage. Careful search was made for any evidence of discontinuity
the vapour pressure surface, but none could be found; the former
nclusion that natrolite and metanatrolite are not distinct phases is
nfirmed, and natrolite must be really monoclinic. The intersection
the isohydric curves noted and discussed in part III of this series
w proves to be spurious, and due to unavoidable inaccuracies in
e isohydric curves for small degrees of hydration.

Analcime, unit cell formula near $Na_{16}Al_{16}Si_{24}O_{96}.16H_2O$, is probably
lly orthorhombic or perhaps tetragonal, but is very markedly

pseudo-cubic, and all its water is likely to have nearly the same volatility, though strictly it should be divided into two or four groups. It is therefore a simple case, since the dehydration fraction x is simply calculable. Two good isobaric dehydration curves have been obtained by G. Friedel.[1] Plotting $\log x/(1-x)$ against $1/T$, the graphs of these two series are a parallel pair of practically straight lines, indicating that E and a probably do not vary with x. The difference between the two series is probably within the experimental error, and may be attributed to small errors in the determination of the water content; it may, however, be real, and due to a small difference in composition. That E and a do not vary with x is confirmed by Friedel's finding that near 250° C., where the water loss at 12 mm. Hg. is about 4 %, a change in the water vapour pressure of 2 mm. causes a change of 0·25 % in the water content; that is, for $\delta \log p = 0{\cdot}06$ to 0·08, $\delta \log x/(1-x) = 0{\cdot}06$, or

$$\delta \log p/\delta \log x/(1-x) = -1 \text{ (approx.)},$$

as it should if E and a do not vary with x. The constants $E = 1{\cdot}80 \times 10^4$ cals., $C = 7{\cdot}25$, give a good representation of the data.

Chabazite, with a unit cell formula $Ca_2Al_4Si_8O_{24}.12H_2O$, crystallizes in space-group D_{3d}^5, or rather in a related group of lower symmetry, but with a very close approximation to the rhombohedral group. According to J. Wyart,[2] the water occupies two sets of equivalent positions with different environments, but the structure proposed is not conclusively proved, and the vapour pressure data shows no indication of any such division. D. Chilton and E. Rabinowitsch[3] regard the existence of two distinct bands in the absorption spectrum of chabazite-iodine as evidence of the existence of two absorption regions of different potential, without continuity between them, that is, of the division of the volatile component between two sets of lattice positions. But chabazite-iodine is known to be pleochroic,[4] and it is probable that the two absorption bands observed are oppositely polarized, pleochroic bands. F. Simon[5] found a discontinuity

[1] G. Friedel, Bull. Soc. Franç. Min., 1896, vol. 19, p. 363.

[2] J. Wyart, Recherches sur les zéolites. Thèse Fac. Sci. Univ. Paris, 1933 [M.A. 5–354]; Bull. Soc. Franç. Min., 1933, vol. 56, p. 103.

[3] D. Chilton and E. Rabinowitsch, Zeits. Physikal. Chem., Abt. B, 1932, vol. 19, p. 107 [M.A. 5–356].

[4] F. Grandjean, Bull. Soc. Franç. Min., 1910, vol. 33, p. 5.

[5] F. Simon, Zeits. Physikal. Chem., 1928, vol. 132, p. 456 [M.A. 5–81]; also Zeits. Elektrochem., 1928, vol. 34, p. 528 [M.A. 5–82].

the absorption of argon and of nitrogen by dehydrated chabazite
ne latter not confirmed by E. Rabinowitsch, see below), and J.
aroni and F. Simon [1] found discontinuities in the curve of magnetic
sceptibility against oxygen absorbed by dehydrated chabazite.
ese results tend to indicate that vapours absorbed by chabazite
cupy more than one set of lattice positions, but they cannot be
garded as very definite evidence, and it appears best to accept the
ar indication of the dehydration data that the lattice positions in
abazite for absorbed gases and vapours are probably all structurally
one set.

G. Friedel's isobaric dehydration data [2] are best represented by
king $E = 1{\cdot}52\,(1+0{\cdot}53x) \times 10^4$ cals., $C_0 = 9{\cdot}61$. With these con-
ants, the isobar computed for a vapour pressure of 10·5 mm. Hg
rees reasonably with Friedel's measurements, the average difference
tween the observed and calculated values of $\log x/(1-x)$ being
06. For the two isolated observations, at p 244 mm., x 0·042, and
10 mm., x 0·066, temperatures of 71° C. and 101° C. respectively
e computed, against 71° C. and 98° C. observed.

Shortly after these calculations had been completed, A. Tiselius
d S. Brohult [3] published a further study of the vapour pressure of
analysed specimen of chabazite. They found Q_x to vary with x,
m $1{\cdot}51 \times 10^4$ cals. near full hydration, through a maximum of
85×10^4 cals. at $x = 0{\cdot}3$, to about $1{\cdot}75 \times 10^4$ cals. at $x = 0{\cdot}5$. The
reement with the values calculated from Friedel's data is grati-
ing, but the maximum in Q_x appeared so remarkable that the
thor undertook a re-computation of the data; a good representation
verage difference between $\log p_{\text{obs.}}$ and $\log p_{\text{calc.}}$, 0·07) is given by
king $C_0 = 8{\cdot}71$ and $E = 1{\cdot}51\,(1+0{\cdot}258x) \times 10^4$ cals. No evidence
a maximum in E (and Q_x) could be found, but it is probable that
e linear relation of E and x is not maintained beyond about
= 0·6. The new constants do not cover the data of Friedel so well
the old; the discrepancy is probably to be assigned to a difference
the composition of the specimens, since E. Rabinowitsch [4] has
own that the vapour pressure of chabazite varies very appreciably

[1] J. Aharoni and F. Simon, Zeits. Physikal. Chem., Abt. B, 1929, vol. 4, p. 175 [M.A. 5–81].
[2] G. Friedel, Bull. Soc. Franç. Min., 1899, vol. 22, p. 5.
[3] A. Tiselius and S. Brohult, Zeits. Physikal. Chem., Abt. A, 1934, vol. 168, 248 [M.A. 6–126].
[4] E. Rabinowitsch, Zeits. Physikal. Chem., Abt. B, 1932, vol. 16, p. 50 [M.A. 3355].

with the composition of the anhydrous mineral. The same cause may account for a failure to correlate the data of G. Tammann[1] and of E. Löwenstein[2] with those of Friedel or of Tiselius and Brohult.

Many workers have studied the absorption by dehydrated chabazite of vapours other than water, but many of the studies were only qualitative, and for others the data were not sufficiently extensive for computation. The only adequate data appear to be those of E. Rabinowitsch (loc. cit.) for chabazite-nitrogen and chabazite-hydrogen. For *chabazite-nitrogen*, the constants $E = 2{\cdot}60\,(1 + 1{\cdot}46x) \times 10^3$ cals., $C_0 = 6{\cdot}11$ give good agreement, the average difference between $\log p_{\text{calc.}}$ and $\log p$ as measured from Rabinowitsch's graphs being 0·20. Each nitrogen molecule was assumed to occupy two lattice spaces.

For *chabazite-hydrogen*, good agreement is obtained by taking $E = 100 + 2550x$ cals., $C_0 = 5{\cdot}16$, each hydrogen molecule occupying one lattice space. The average agreement is 0·27. Since E is so small, of the same order as the average kinetic energy of the molecules at the temperatures of experiment, the approximations dependent on $N\epsilon/RT$ being large will not hold, and these constants can only be regarded as a rough approximation. Nevertheless, the remarkably low value of E for chabazite-hydrogen near complete saturation, and its marked increase as the hydrogen is removed, are reasonably well established.

The vapour pressure data for *heulandite* and for *stilbite* proved impossible of interpretation, the former because the water is divided into at least three, possibly six sets, and only isobaric data are available, the latter because the true saturation water content of stilbite and the possible grouping of the water remain quite unknown.

Very few ' zeolitic ' compounds other than the zeolites themselves have been examined in sufficient detail to deduce the vapour pressure constants. The system *palladium-hydrogen* has been the subject of numerous studies, and it has proved possible to explain the behaviour of this system fairly satisfactorily on the new theory, but the results will not be discussed here, as the treatment is more complex, owing to the dissociation of the hydrogen.

[1] G. Tammann, Zeits. Physikal. Chem., 1897, vol. 27, p. 325; Ann. Phys. Chem. (Wiedemann), 1897, vol. 63, p. 16.

[2] E. Löwenstein, Zeits. Anorg. Chem., 1909, vol. 63, p. 69.

D. Balarew [1] has made some observations on the vapour pressure *calcium sulphate hemihydrate*, $12CaSO_4.6H_2O$, which he interprets as dicating a truly univariant equilibrium in a substance which ptical and X-ray data show [2] is definitely zeolitic in nature. His ta are not very accurate, but it is easily shown that they are asonably reproduced by taking $E = 2{\cdot}15 \times 10^4$ cals., and $C = 12{\cdot}13 - \log(1 - 0{\cdot}94x)$. These constants are necessarily very approximate the data are so few.

A series of very valuable data has been obtained by W. Lange, rking with the benzene sulphonates of potassium, rubidium, and esium.[3] Unfortunately, much of the data consists of isothermal rves only, which are inadequate for the deduction of vapour essure constants, and X-ray work is lacking. But experimental ta consisting of both isothermal and isobaric curves were obtained r *potassium benzene sulphonate* with H_2S, N_2O, CO_2, NH_3, CH_3Cl, and gon. From these results, the following constants were calculated, d reproduce the experimental figures very well: N_2O, $E = 8{\cdot}75 \times 10^3$ ls., $C = 8{\cdot}48$; CO_2, E $7{\cdot}18 \times 10^3$ cals., $C = 7{\cdot}30$; H_2S, E $8{\cdot}33 \times 10^3$ ls.,[4] $C = 7{\cdot}19$; CH_3Cl, $E_0 = 1{\cdot}19 \times 10^4$ cals., $C_0 = 9{\cdot}60$, while $+f(x)\}$ is almost but not quite linear, approaching $(1 + 0{\cdot}15x)$. All ese four gases occupy one lattice position each, so that the saturated mpounds have formulae analogous to that of the zeolitic hydrate $4(C_6H_5SO_3K).G$, where G represents one molecule of the gas. For mmonia, the data proved barely adequate to compute constants, t $E = 8{\cdot}93 \times 10^3$ cals., $C = 6{\cdot}65$ gave a fairly good reproduction the experimental data for compositions up to $4(C_6H_5SO_3K).NH_3$; e data are insufficient to give any indication whether the ammonia

[1] D. Balarew, Zeits. Anorg. Chem., 1926, vol. 156, p. 238; ibid., 1927, vol. 163, 137; Kolloid-Zeits., 1929, vol. 48, p. 63.

[2] G. Linck and H. Jung, Zeits. Anorg. Chem., 1924, vol. 137, p. 407; H. Jung, d.,' 1925, vol. 142, p. 73; W. Feitknecht, Helv. Chim. Acta, 1931, vol. 14, 85; E. Onorato, Periodico Min. (Roma), 1932, vol. 3, p. 73; P. Gallitelli, ibid., 33, vol. 4, p. 132; W. A. Caspari, Nature, 1934, vol. 133, p. 648. The objec- ns of P. Gaubert (Bull. Soc. Franç. Min., 1934, vol. 57, p. 252) cannot be cepted as valid [M.A. 6–58].

[3] W. Lange and G. Lewin, Ber. Deut. Chem. Gesell., 1930, vol. 63B, pp. 2156, 54; W. Lange and G. Krueger, Zeits. Anorg. Chem., 1933, vol. 216, p. 49; . Lange, ibid., 1934, vol. 219, p. 305.

[4] The isothermal data for H_2S for $-60{\cdot}6°$ C. are not in agreement with the otherm for 0° C. and the isobar for 760 mm., the observed pressures being much o high; they have therefore been rejected. Calorimetric measurements gave H_2S, $Q_x = 9{\cdot}94 \times 10^3$ cals., or $E = 9{\cdot}9 \times 10^3$ cals.

absorbed in excess of this composition occupies a second set of lattice positions, or whether there is a polymorphic change.

Lange's data with argon are particularly interesting, proving the existence of the definite 'zeolitic' compound $4(C_6H_5SO_3K).Ar$, with a low heat of formation. With $E = 400$ cals., $C = 3{\cdot}6$, the experimental data are represented, but an impossible value of the condensation area a is found. It is true that the constants are only approximate, since $N\epsilon/RT$ is not large, E being so small, but it does not seem probable that correction for this would resolve the discrepancy. This is the only serious discrepancy so far encountered, and it is not clear how far it arises from the deficiencies of the equation, and how far from inadequacy of the data. It is also possible that E and a may vary with x, which might make a considerable difference, though it has not been possible to prove any such variation.

The dimensions of the water-bearing channels in the zeolites.

The constants C $(=5{\cdot}22+\log\sqrt{E/aD\chi})$ and E have now been derived for several zeolites and related compounds, and in most cases the crystal structure is sufficiently known to fix the value of D, the spacing of the water molecules along the channels. Hence, by assuming $\chi = 1$, a maximum value of the 'condensation area', a, can be calculated; and as $a = \pi(r-\rho)^2$, the difference, $r-\rho$, between the effective radii of the molecules of the volatile component and of the channels can be obtained. Assuming a value for the molecular diameter of water, the diameters of the channels are found (table V). In the case of chabazite, there are also data for hydrogen and nitrogen, and the lattice shrinkage is negligible. Hence, accepting the channel diameter, the effective molecular diameters of nitrogen and hydrogen are found, and agree well with the commonly accepted values. The agreement is, perhaps, somewhat fortuitous, as an appreciable change could be made in E and C without greatly altering the average agreement between $\log p_{obs.}$ and $\log p_{calc.}$

For Lange's potassium benzene sulphonate compounds, X-ray data to fix D are lacking; but assuming $D = 10$ Å., which cannot be far out, and $r = 2{\cdot}14$ Å. (a value selected to give optimum agreement), satisfactory values of the molecular radii are found for all the gases studied (except argon).

The generally reasonable values of the channel and molecular radii

ınd for all the zeolitic compounds studied furnishes further evidence favour of the vapour pressure equation here proposed.

Table IV. Observed and accepted values for the radii of the water-bearing annels in several zeolitic compounds, and for the molecular radii of several ses.

n-volatile mponent.	Volatile component.	Spacing, D, of the volatile component.	$r-\rho$. (obs.)	Channel radius, r.	Molecular radius, ρ, of the volatile component. Observed.	Accepted.
ingtonite	Water	6·53 Å.	0·070 Å.	1·52 Å.	—	1·45 Å.‡
solite	Water	6·53	0·028	1·48	—	1·45‡
trolite	Water	6·60	0·049*	1·50	—	1·45‡
		6·60	0·005†	1·46	—	1·45‡
alcime	Water	5·89	0·26	1·71	—	1·45‡
abazite	Water	7·47	0·014§	1·46¶	—	1·45‡
			0·04‖	1·49¶	—	1·45‡
abazite	Nitrogen	7·47	0·59	1·49**	0·90 Å.	1·02‡‡
abazite	Hydrogen	7·47	0·69††	1·49**	0·80	0·94‡‡
SO_4	Water§§	6·3 ?	0·001 ?*	1·45	—	1·45‡
		6·3 ?	0·0006 ?†	1·45	—	1·45‡
H_5SO_3K	N_2O	10**	0·04	2·14**	2·10	2·03‡‡
H_5SO_3K	CO_2	10**	0·15	2·14**	1·99	1·99‡‡
H_5SO_3K	CH_3Cl	10**	0·012	2·14**	2·13	2·0–2·1
H_5SO_3K	NH_3	10**	0·33††	2·14**	1·81	1·80‡‡
H_5SO_3K	H_2S	10**	0·17	2·14**	1·97	2·04‡‡

* At full hydration.
† Completely dehydrated.
‡ L. Pauling, Zeits. Krist., 1930, vol. 72, p. 485.
§ From Friedel's data.
‖ From Tiselius and Brohult's data.
¶ J. Wyart (loc. cit.) found 1·35 Å. approximately from X-ray data; Schmidt (loc. cit.), from a consideration of the largest molecules absorbed by ıydrated chabazite, found 1·75 Å. approximately.
** Assumed.
†† Approximately.
‡‡ Chem. Soc., Annual Reports, 1931, p. 303.
§§ Hemihydrate.

The condition of the water in the zeolites.

The question, whether the water in zeolites occupies definite lattice ›itions or no, has been the subject of some controversy. At one treme, it has been supposed that the water occupies definite, fixed ttice positions, while, at the other extreme, the water is supposed erely to fill in the empty spaces in the structure, packing irregularly to them, and taking no real part in the crystal structure.

The latter view would imply that the water or other volatile component present at saturation need not always be an integral number of molecules per unit cell. Evidence in this direction has been advanced by E. Rabinowitsch (loc. cit.); chabazite absorbed 300 c.c. water vapour, 350 c.c. H_2, 270 c.c. NH_3, 175 c.c. N_2, 170 c.c. CO_2, and over 400 c.c. He per gram, all calculated to normal temperature and pressure. The calculated volume of gas absorbed per gram chabazite if there are 12 lattice positions per unit cell is 335 ± 10 c.c. Now all the above figures are obtained by extrapolation, and for NH_3 and He the extrapolation was very considerable and the result correspondingly open to doubt; moreover J. Sameshima [1] found that the ammonia absorbed by dehydrated chabazite is molecularly equivalent to the water removed. The figures for H_2 and H_2O are clearly within the experimental error of the calculated 335 c.c., while N_2 and CO_2 evidently occupy two lattice positions per molecule.

There is very little other data available as to saturation values, but it may probably be assumed that the values obtained by O. Weigel and E. Steinhoff [2] for ethyl and methyl alcohols at atmospheric pressure and temperatures near their boiling points are not far from saturation values. These figures, 110 c.c. C_2H_5OH and 165 c.c. CH_3OH per gram anhydrous chabazite, agree well with the conclusion that in thomsonite one molecule of ethyl alcohol replaces three, and one of methyl alcohol two molecules of water, in accordance with their molecular dimensions.

A quantity of other experimental data has been held to support the view that the water (or other volatile component) in zeolites does not occupy definite lattice positions, but in large measure it does not lead unequivocally to this conclusion. Thus E. Rabinowitsch (loc. cit.) regarded a failure to catalyse the reaction $N_2 + 3H_2 \rightleftharpoons 2NH_3$ by dehydrated chabazite as evidence against the theory of definite lattice positions, but although this catalysis failed, O. Weigel and E. Bezner [3] and T. Baba [4] have shown that chabazite catalyses the reaction $CS_2 + 3H_2O \rightleftharpoons 2H_2S + H_2CO_3$, and W. Lange and G. Lewin (loc. cit.) have shown that potassium benzene sulphonate catalyses the reaction $C_2H_4 + H_2S \rightleftharpoons C_2H_5SH$.

[1] J. Sameshima, Bull. Chem. Soc. Japan, 1929, vol. 4, p. 96 [M.A. 5–79].

[2] O. Weigel and E. Steinhoff, Zeits. Krist., 1925, vol. 61, p. 125 [M.A. 2–528].

[3] O. Weigel and E. Bezner, Sitzungsber. Gesell. Naturwiss. Marburg, 1927, vol. 62, p. 57 [M.A. 5–78].

[4] T. Baba, Bull. Chem. Soc. Japan, 1930, vol. 5, p. 190 [M.A. 5–79].

F. Simon[1] has found a value of approximately 3 cals. per gram r the specific heat of hydrogen absorbed on chabazite at −240 to 230° C., but the data do not appear adequate to justify his con- usion that the molecules do not occupy definite lattice positions.

The problem has been attacked by X-ray methods, but here again e results are not quite conclusive. Some workers[2] have supposed at because no very marked differences were observed between the -ray photographs of zeolites before and after dehydration, the water nnot occupy definite lattice positions. Others[3] have observed anges, in approximate agreement with those expected on theoretical ounds for fixed water molecules. But in no instance has any tempt been made to calculate the changes to be expected, firstly the assumption of fixed water molecules, and secondly on the sumption that the water molecules are irregularly distributed over the space not occupied by other atoms. Much the most effective idence on the question is to be found in the crystal structures posed by W. H. Taylor for analcime, thomsonite, edingtonite, trolite, and scolecite; in these structures there are several spaces o which water molecules could enter, but the saturation water ntent does not by any means correspond to the complete filling them all, and it is difficult to see, on the extreme 'sponge' theory, y they should not all be filled.

Further support for the idea of definite lattice positions for the ter is provided by the calorimetric measurements of the heats of dration of natrolite, edingtonite, and mesolite, and by the data A. Tiselius (see below) on the rate of diffusion of water in heulan- e. The large values found for the heats of hydration (about ,000 cals. per gram-mol. H_2O) show that the water is very unlikely be held by mere adsorption, but must be more firmly attached, d it is difficult to imagine water irregularly filling all the lattice vities as held by other than weak van der Waals forces. For heulan- e, Tiselius found that the diffusion coefficient showed a marked riation with temperature, indicative of an activation energy of the der of 5000 cals. per gram-mol. H_2O at some stage of the diffusion

F. Simon, Zeits. Elektrochem., 1928, vol. 34, p. 528 [M.A. 5–82].

W. Hartwig, Zeits. Krist., 1931, vol. 78, p. 173 [M.A. 5–29] (analcime); Lengyel, Zeits. Physik, 1932, vol. 77, p. 133 [M.A. 5–355] (chabazite).

W. H. Taylor, Zeits. Krist., 1930, vol. 74, p. 1 [M.A. 4–369]; W. H. Taylor, A. Meek, and W. W. Jackson, ibid., 1933, vol. 84, p. 373 [M.A. 5–354]; W. H. ylor and R. Jackson, ibid., 1933, vol. 86, p. 53 [M.A. 5–354]; J. Wyart, loc.

process. This is most readily understood if it is assumed that a definite integral number of equilibrium lattice positions per unit cell are available for water molecules, and that the molecules spend most of their time in these positions. But since their activation energy of migration is relatively small, they will change their positions with some frequency, and will show that mobility which is so characteristic of zeolitic hydrates.

The rate of diffusion of water in a zeolite crystal.[1]

When a dehydrated crystal of a zeolite is allowed to reabsorb water, the rehydration process consists of two parts, the absorption of water by the surface layer, and its diffusion into the body of the crystal. The former process is governed by the equation

$$\begin{aligned}(dx/dt)_{\text{surface}} &= [axNp\,.\,e^{-N\eta/RT}]/\sqrt{2\pi MRT} - \\ &\quad -[2(1-x)\sqrt{2N(\epsilon-\eta)}\,.\,e^{-N\epsilon/RT}]/\pi\chi D\sqrt{M} \\ &= 2(1-x)\sqrt{2N(\epsilon-\eta)}\,.\,e^{-N\epsilon/RT}.(p-p_x)/\pi\chi Dp_x\sqrt{M},\end{aligned}$$

where p_x is the equilibrium vapour pressure corresponding to the momentary dehydration fraction x.

If the diffusion through the body of the crystal is slower than the absorption of water (which will not always be the case), this surface layer will be in a practically steady state, with a water content but little below that corresponding to equilibrium with the external pressure of water vapour. If this condition is not fulfilled, the rehydration phenomena will be much more complex, but, if it is fulfilled, the process can be treated on the assumption that the water content in the surface layer remains steady at approximately the equilibrium value.

The second process, the diffusion of water into the body of the crystal, is more difficult to treat. Using the same symbols as before, we may first consider a layer within the crystal, normal to the water channels, of area 1 sq. cm. and thickness D. Then the number of molecules in this layer having sufficient energy μ to migrate[2] will be $\nu(1-x)e^{-N\mu/RT}$, but only a fraction $(x+\delta x)$ of them will be opposite vacant positions in the next layer (which has a dehydration fraction $(x+\delta x)$) and so be able to migrate, and only half of these will

[1] It need hardly be mentioned that the results here obtained for the diffusion of water in a zeolitic hydrate will apply to the diffusion of the volatile component in any zeolitic compound.

[2] The activation energy, μ, for migration within the lattice is likely to be considerably less than the activation energy, ϵ, for escape from the lattice.

moving in the right direction at any instant. The activation energy will vary with x, and may be written $\mu = \mu_0\{1+\psi(x)\}$. Assuming as before that the motion of the molecules approximates simple harmonic motion, and introducing a factor χ to correct for this assumption, their rate of migration from the first to the second layer will be:

$$\nu(1-x)(x+\delta x)\sqrt{2N\mu_0}\{1+\psi(x+\tfrac{1}{2}\delta x)\}\,.\,e^{-N\mu_0\{1+\psi(x)\}/RT}/\pi\chi D\sqrt{M},$$

provided that $N\mu_0/RT$ is fairly large.

To find the rate of change of the water content of a layer of the zeolite, of dehydration fraction x, the rate of influx of molecules from and efflux to the neighbouring layers must be found and summed algebraically. Assuming the neighbouring layers have dehydration fraction $x+\delta_1 x$ and $x+\delta_2 x$, then:

$$\begin{aligned}\partial x/\partial t = {} & [(1-x)(x+\delta_1 x)\sqrt{2N\mu_0}\{1+\psi(x+\tfrac{1}{2}\delta_1 x)\}\,.\,e^{-N\mu_0\{1+\psi(x)\}/RT}]/\pi\chi D\sqrt{M} \\ & +[(1-x)(x+\delta_2 x)\sqrt{2N\mu_0}\{1+\psi(x+\tfrac{1}{2}\delta_2 x)\}\,.\,e^{-N\mu_0\{1+\psi(x)\}/RT}]/\pi\chi D\sqrt{M} \\ & -[x(1-x-\delta_1 x)\sqrt{2N\mu_0}\{1+\psi(x+\tfrac{1}{2}\delta_1 x)\}\times \\ & \qquad e^{-N\mu_0\{1+\psi(x+\delta_1 x)\}/RT}]/\pi\chi D\sqrt{M} \\ & -[x(1-x-\delta_2 x)\sqrt{2N\mu_0}\{1+\psi(x+\tfrac{1}{2}\delta_2 x)\}\times \\ & \qquad e^{-N\mu_0\{1+\psi(x+\delta_2 x)\}/RT}]/\pi\chi D\sqrt{M}.\end{aligned}$$

The dehydration fractions $x+\delta_1 x$ and $x+\delta_2 x$ can be expressed in terms of the position of the layer in the crystal. If z be the coordinate measuring the distance of the layers from the surface, let the first considered layer, of dehydration fraction x, have position z, while $x+\delta_1 x$ corresponds to a position $z+D$ and $x+\delta_2 x$ to a position $z-D$. Then

$$\delta_1 x = D\partial x/\partial z + \tfrac{1}{2}D^2\partial^2 x/\partial z^2 + \ldots,$$

and

$$\delta_2 x = -D\partial x/\partial z + \tfrac{1}{2}D^2\partial^2 x/\partial z^2 - \ldots.$$

With this substitution, and neglecting higher powers of D (since D is a very small quantity), the above expression reduces to:

$$\partial x/\partial t = K\partial^2 x/\partial z^2 + (\partial K/\partial x)(\partial x/\partial z)^2 = \partial(K\partial x/\partial z)/\partial z,$$

where $K = [D\sqrt{2N\mu_0}\{1+\psi(x)\}/\pi\chi\sqrt{M}]\times e^{-N\mu_0\{1+\psi(x)\}/RT}.[1+x(1-x)\psi'(x)N\mu_0/RT]$.

If μ does not vary with x, $\psi(x)$ and $\psi'(x)=0$, and the equation reduces to

$$\partial x/\partial t = K_0\partial^2 x/\partial z^2,$$

where

$$K_0 = [D\sqrt{2N\mu_0}/\pi\chi\sqrt{M}]\,.\,e^{-N\mu_0/RT}.$$

The above equations were derived for one particular direction in the crystal only; they may be formally generalized for all directions by writing $\mu = \mu_{00}\{1+\zeta(x,\theta)\}$ and $D = D_0\{1+\xi(\theta)\}$, where θ defines direction in the crystal; D_0 and μ_{00} refer to the direction $\theta = 0$, which may conveniently be parallel to the water channels, in which direction μ_0 is likely to be a minimum. The generalized diffusion constant then becomes:

$$K = [D_0\{1+\xi(\theta)\}\sqrt{2N\mu_{00}\{1+\zeta(x,\theta)\}}/\pi\chi\sqrt{M}].e^{-N\mu_{00}\{1+\zeta(x,\theta)\}\ RT} \times [1+x(1-x)N\mu_{00}\partial\zeta(x,\theta)/RT\partial x].$$

Even this equation is only applicable provided all the water molecules are structurally of the same kind, which is often not the case. A general treatment is not at present practicable, as the transfer of water molecules between positions belonging to different sets has to be considered. But two important special cases can be dealt with. If the activation energy differences for dehydration and rehydration, E, are approximately the same for the several sets of water molecules, then to a first approximation, the water can all be considered as belonging to one set for the calculation of the diffusion constant. And if the values of E differ markedly for the several sets, then the less volatile sets must be almost completely filled before any water can remain stably in the more volatile sets. Then if all the sets of positions are very nearly filled, except the most volatile one, the water in the less volatile positions can be neglected for the purpose of calculating the diffusion constant; but if some of the less volatile positions are vacant, it is probably permissible to calculate the diffusion as if all the empty positions belonged to one set. For example, in the case of heulandite, where there are $24H_2O$ per unit cell, occupying three (or possibly six) sets of lattice positions, if it can be assumed that the values of E for the several sets are markedly different, then a crystal having $20H_2O$ present per unit cell will have two sets of positions almost completely filled, and one half-filled; here the two full sets may probably be neglected, and the value of x, 0·5, for the most volatile set taken for diffusion purposes. But a crystal having only $14H_2O$ present per unit cell will have one set almost completely empty, one filled, and one containing $6H_2O$; here the figure to be taken for diffusion purposes is not $x = 0{\cdot}25$, the figure for the partially filled set of positions, but $x' = (8+2)/(8+8) = 0{\cdot}625$, derived by including the (almost) empty set of positions.

The above treatment of the case where there are lattice positions

several kinds is only tentative; it is based on the assumption that here E is large, μ is likely to be large also, so that migration from less volatile, completely filled set of positions to a more volatile, completely filled set is likely to be negligible; but migration from less volatile, partially filled set of positions to a more volatile, empty set will probably occur, though the migrating molecules are not likely to remain long in their new positions.

The only quantitative work yet done on the diffusion of water in zeolite is that of A. Tiselius,[1] on heulandite. The relative volatility of the three or six sets into which the water of heulandite must be divided is not known, so that the application of the new equation to this data is necessarily tentative; but if it is assumed that the water is divided into three groups of markedly different volatility, treatment on the lines suggested above becomes possible.

Unfortunately, the variation of the diffusion coefficient with temperature does not give the activation energy of migration directly, since

$$\partial \log_{10} K/\partial(1/T) = -[N\mu_0\{1+\psi(x)\}(\log_{10}e)/R] \times [1-x(1-x)\psi'(x)/\{1+x(1-x)\psi'(x)N\mu_0/RT\}].$$

This makes the derivation of the several constants more difficult, but the last factor of the above expression is fortunately usually nearly unity, so that the method of successive approximations is available.

The data for diffusion normal to the face $t(201)$ are the most complete and lead unambiguously to a value for the activation energy $(N\mu)_{201} = 4{\cdot}79(1+0{\cdot}13x) \times 10^3$ cals. per gram-mol. of water, and for the constant $\log D/\chi = \bar{8}{\cdot}55$, or $D/\chi = 3{\cdot}6$ Å. approx., a quite reasonable value. The X-ray data is not sufficient to fix D with certainty, but it must be a simple sub-multiple of 6·7 Å. The values of the diffusion constant K_{201} for several temperatures and water contents, calculated from these constants, are given in table V, and compared with Tiselius's measurements.

For diffusion normal to the face $c(001)$, the data are much less complete; the most probable value for the activation energy is approximately $(N\mu)_{001} = 7{\cdot}3(1+0{\cdot}08x) \times 10^3$ cals. per gram-mol. of water, which leads to the rather high figure for $\log D/\chi$ of $\bar{7}{\cdot}28$, or $\chi = 19$ Å. Values of K_{001} for several temperatures, and of the ratio

[1] A. Tiselius, Nature, 1934, vol. 133, p. 212; Zeits. Physikal. Chem., Abt. A, 1934, vol. 169, p. 425 [M.A. 6–126].

K_{201}/K_{001} for several water contents are compared with Tiselius' measurements[1] in table V.

TABLE V. Diffusion data for heulandite. Calculated values from the new equation, compared with the experimental values of A. Tiselius. Water percentages calculated on the anhydrous mineral.

H_2O %		19	18	17	16	15	14
x		0·10	0·255	0·41	0·56	0·71	0·865
$K_{201} \times 10^7$ (20° C.)	Obs.	3·3, 3·5 4·1	4·0, 4·1 4·2	4·0, 4·0 4·2	3·5, 3·6	2·6, 2·7	2·1, 2·0
	Calc.	4·47	4·27	3·80	3·32	2·70	2·14
Temp. °C.		20·0	33·8	46·1	60·0	75·0	
$K_{201} \times 10^7$, for $x = 0·71$	Obs.	2·7	4·1	4·8	7·6	11·1	
	Calc.	2·70	4·10	5·60	7·90	11·0	
H_2O %		18·5	17·5	16·5	15·5	14·5	13·5
x		0·18	0·33	0·48	0·64	0·79	0·94
$\frac{K_{201}\,(46° C.)}{K_{201}\,(20° C.)}$	Obs.	1·7	2·0	1·8	1·8	1·8	1·7
	Calc.	1·93	1·93	1·94	1·98	2·03	2·09
Temp. °C.		20·0	33·0	46·1	60·0	75·0	
$K_{001} \times 10^7$, for $x = 0·71$	Obs.	0·23	0·45	0·66	1·45	2·8	
	Calc.	0·25	0·48	0·74	1·23	2·05	
H_2O %		13·21	14·43	15·50	16·25	17·36	
x		0·96	0·80	0·64	0·52	0·35	
K_{201}/K_{001} (20° C.)	Obs.	13·0	11·6	12·2	10·2	11·6	
	Calc.	11·0	11·1	11·6	11·8	11·9	

The above constants only relate to the most volatile group of water molecules in heulandite, that is, to material containing more than 13·11 % of water, calculated on the anhydrous material. Tiselius found that at lower water contents the diffusion constant fell sharply, decreasing by a factor of about 10 between 13 and 11 % H_2O (anhydrous basis). This is doubtless due to a sharp increase in the activation energy, for there is no reason to expect any marked change in D, so that the experimental data tend to justify the above assumption as to the relative volatility and mobility of the groups of water molecules.

Thus the available data, while not adequate fully to test the proposed equation, are in good agreement with it. A better test of the equation would be obtained with data for zeolites having only one set of water lattice positions, such as chabazite, natrolite, or analcime,

[1] Tiselius found the diffusion to be faster normal to $t(201)$ and $s(\bar{2}01)$ than normal to $c(001)$; according to P. Gaubert (Bull. Soc. Franç. Min., 1929, vol. 52, p. 162 [M.A. 4–377]) the opposite is the case.

the experimental difficulties would be much greater with dandite.

Summary.

A simple kinetic treatment leads to an equation for the dissociation ssure of a 'zeolitic' compound of a volatile and a non-volatile nponent:

$$\log_e p = \log_e 4\sqrt{NR(\epsilon-\eta)/aND\chi\sqrt{\pi}} + \tfrac{1}{2}\log_e T - \log_e x/(1-x) - N(\epsilon-\eta)/RT,$$

ere p is the equilibrium pressure in dynes per sq. cm., N the ogadro number, R the gas constant in ergs, T the absolute nperature, ϵ and η the activation energies in ergs per molecule of aile component for dissociation and re-combination respectively, he fraction of unoccupied lattice positions for the volatile com- nent (assumed all of the same kind), D the distance between lattice tions for the volatile component, measured along the channels ng which the latter migrates, a the difference between the effective ss-sections of a molecule of the volatile component and of a nnel, and χ a constant not greatly different from unity.

The more usual case where the volatile component occupies several erent sets of lattice positions is also considered, also the variation - η and in a with x. It is emphasized that the equation can only regarded as a first approximation, but it represents the available a reasonably well.

The approximate 'condensation areas', a, found for several 'zeo- c' systems are discussed and shown to be in reasonable agreement h what is known of the size of the water-bearing channels in lites and of the dimensions of the volatile molecules concerned.

The condition of the water in the zeolites is discussed in the light the evidence now available.

Kinetic treatment of the rate of diffusion of the volatile component, the assumption that it only occupies one set of lattice positions, ds to an expression for the diffusion constant:

$$= [D_0\{1+\xi(\theta)\}\sqrt{2N\mu_{00}\{1+\zeta(x,\theta)\}}/\pi\chi\sqrt{M}] \times e^{-N\mu_{00}\{1+\zeta(x,\theta)\}/RT}.[1+x(1-x)N\mu_{00}\partial\zeta(x,\theta)/RT\partial x],$$

here θ defines direction in the crystal, D_0 the distance between tice positions for the volatile component in the direction $\theta = 0$, d $D_0\{1+\xi(\theta)\}$ the distance in the direction θ, μ_{00} the activation

energy of migration in ergs per molecule of the volatile component for $x = 0$ and $\theta = 0$, and $\mu_{00}\{1 + \zeta(x, \theta)\}$ the energy for x, θ; M is the molecular weight of the volatile component. The other symbols have the meaning defined above.

The case where the volatile component occupies more than one set of lattice positions is considered, and it is shown that on certain assumptions the experimental data of A. Tiselius are reasonably well reproduced.

The late Palaeozoic quartz-dolerites and tholeiites of Scotland.

(With Plate V.)

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1. Introduction and Literature.

OWARDS the close of the Carboniferous period in Britain, igneous activity, which had been prominent from time to time ɔughout the system, broke out afresh in a new form affecting a ɛ area of the country between the Moray Firth and the River s. This activity was entirely hypabyssal in character, the intru- s consisting of basic dikes and sills belonging without exception he tholeiite magma-type of Dr. W. Q. Kennedy [1] and W. Wahl. se in the north of England include the famous Whin Sill and e been studied in great detail, particularly by Professor A. mes [2] and by Dr. J. A. Smythe.[3] The same cannot be said of r Scottish representatives. They possess, indeed, an abundant ature and several excellent publications deal with the intrusions imited areas, but there is no connected account of them as a le. Many districts, in fact, appear to have escaped investigation ost completely. The present paper is an attempt to fill some of

W. Q. Kennedy, Trends of differentiation in basaltic magmas. Amer. n. Sci., 1933, ser. 5, vol. 25, pp. 240–242.

A. Holmes and H. F. Harwood, The age and composition of the Whin Sill related dikes of the north of England. Min. Mag., 1928, vol. 21, pp. 493–542.

J. A. Smythe, A chemical study of the Whin Sill. Trans. Nat. Hist. Soc. of humberland, Durham, and Newcastle-upon-Tyne, 1930, vol. 7, pp. 16–150.

the major gaps in the literature and to give, with the aid of new chemical and micrometric data, a more comprehensive account of the whole suite than has hitherto been published. No claim to completeness is made, for a great deal of work still remains to be carried out on these intrusions.

Only the more important references in the literature are given in the list below, in which redundance is avoided as far as possible. Attention may also be directed, however, to the Economic Memoirs of the Geological Survey of Scotland, in particular to those of the Fifeshire, Kinross-shire, and Stirlingshire coal-fields. Numerous brief references to the field relations of the intrusions occur throughout the text of these publications.

It is unnecessary to summarize this long list of papers. The best general petrological accounts are those of Professor J. D. Falconer (15), Dr. G. W. Tyrrell (21), and Sir John Flett (22, pp. 301–311), while an admirable summary of the field evidence relating to the age of the intrusions is given by Professor E. B. Bailey (30, pp. 150–151). The two most important advances in the study of the suite are the recognition by J. J. H. Teall (4) of primary quartz as micropegmatite in the Lothian sills and their resemblance to the Whin Sill, and the discovery by C. T. Clough (8) that the E.–W. dikes are cut by members of the NW. Tertiary swarms and may therefore be of Palaeozoic age.

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2. Field Characters.

Distribution.—A sketch-map (text-fig. 1) showing, as far as possible, all the recorded dikes together with the areas in which the associated sills occur is given on p. 135, and it will be seen at once that the distribution of the intrusions presents certain well-marked features. The sills are confined almost entirely to strata of Carboniferous age, the one possible exception being the sill of Corriefodly in Strathmore (33, p. 87) where the country-rock is of Lower Old Red Sandstone age. They are prominent in the middle and eastern portions of the Midland Valley but are completely absent from the Carboniferous strata west of Glasgow.

The dikes, on the other hand, are found in all formations up to and including the Coal Measures. Apart from sporadic outlying occurrences they appear to belong to two great swarms—one trending E.–W. across the country from Dunbar to Jura, and the other trending ENE. from Stonehaven to the head of Loch Fyne. Many of the separate outcrops mapped in Strathmore, the NE. Grampians and Aberdeenshire (37, p. 323) might be connected up to form continuous dikes with some probability, but the country in this region is so thickly covered by drift that exposures are very poor. The northern swarm seems to find its maximum development in the district between Callander and Loch Tay and tends to spread out slightly both ENE. and WSW. of this focus. In the case of the southern swarm no sign of spreading is seen either to the E. or W of the region of maximum development which appears to be in the neighbourhood of Falkirk. A curious feature is the relative absence of dikes from southern Fifeshire—a district where sills are exceedingly prominent. The significance of the distribution of both dikes and sills will be withheld until a later stage.

Form and Topography.—In most districts both dikes and sills tend to stand out as prominent features of the landscape owing to their superior hardness, and it is only in regions where the country-rock is

FIG. 1. Sketch-map showing distribution of quartz-dolerite and tholeiite dikes and associated sills.

resistant to weathering and thickly covered by drift (e.g. Strathmore) that exposures are poor. The sills usually show well-marked escarpments along which more or less rounded rectangular joint blocks project from the rich, warm-brown soil so characteristic of the weathering of these intrusions. Spheroidal weathering is frequently

visible, but the columnar jointing often seen in the Carboniferous olivine-dolerite and teschenite sills is very rare. Some of the sills reach a considerable thickness, as, for instance, the main sill of the Kilsyth-Croy district, which has been proved by a diamond bore to be over 300 feet thick (30, p. 153). Another feature which distinguishes them from the olivine-dolerites and teschenites is their tendency to change their horizon abruptly. This renders estimates of their area a difficult matter.

The dikes usually stand out as conspicuous ridges, often wooded, and sometimes with wall-like sides exhibiting basaltic selvages. A very common breadth is about 60 feet, but numerous examples are known over 100 feet across, one between Croy and St. Flanan (30, 157) reaching a width of 190 feet. On several of the older one-inch maps of the Geological Survey breadths of 300 feet or more are shown, but when these localities were visited by the author it was found that in no case did the dike in question measure much more than 100 feet across. Some of the dikes rival in length the great Tertiary examples which cross the Southern Uplands, one actually stretching from Newton Hill in NE. Fife to the head of Loch Fyne—a distance of over 80 miles. The majority of them have risen vertically upwards.

Relation of dikes to sills.—As in the north of England, the dikes and sills of the suite are petrologically identical, but the relationship between the two types of intrusions can be made out more easily in Scotland. It has been suggested by B. N. Peach, upon convincing field evidence, that the Lenzie-Torphichen dike acted as the feeder of the adjacent sill complex, and this conclusion has been confirmed by the work of C. B. Crampton in the Mollinburn district (30, pp. 149–150). On the other hand, a sill at Ravenscraig in the Bathgate Hills may be definitely shown to cut an E.–W. dike (22, p. 285), while a dike in the Kilsyth-Croy complex has all the appearance of cutting a sill (30, p. 157). Consideration of the evidence seems to indicate that both dikes and sills belong to the same period of intrusion, but that this period was somewhat prolonged—a conclusion confirmed by the tectonic evidence as outlined below.

Tectonics.—Detailed examination of the relevant one-inch maps shows clearly that the suite has a close connexion with the faulting and folding which affected the country at the close of the Carboniferous time. Taking the dikes first it will be noted that those of the southern swarm (occurring in Carboniferous strata) maintain an

..–W. trend with little variation other than local. They are obviously connected with the great E.–W. normal faults which cross the Midland Valley and are the result of tension from N. to S. At several places between Linlithgow and Glasgow the dikes appear to have risen upwards along the fault fissures. Elsewhere the dikes are found in older rocks and here their trend is determined by the result of competition between movements of the Caledonian and Hercynian age. In each district the dikes follow roughly the direction of the prominant faults. In northern Perthshire the Caledonian trend is prominant, but the members of the northern swarm have an ENE. trend along Strathmore and the Highland Border swinging round to E.–W. in western Perthshire and Argyllshire. The Hercynian movements seem also to have prevailed in the western portion of the southern swarm as well as in northern Aberdeenshire. On the maps of Highland areas a great many faults, whatever their trend, are shown as cutting the dikes without shifting the outcrop. Since most of the dikes are vertical, this may often be the case provided the dislocation causes no horizontal displacement, but it is exceedingly doubtful whether this relationship holds good as frequently as recorded on the maps. It is, in fact, probable that many of the dikes are actually later than the faults, as in the Midland Valley. Another feature of the Scottish dikes is the apparent absence of the echelon arrangement so prominent in their north of England neighbours and considered by Professor Holmes (loc. cit., pp. 514–515) to be the result of differential rock flowage which he compares to the conditions obtaining in valley glaciers where a series of marginal crevasses in echelon formation is a common phenomenon. Some of the Strathmore outcrops may possibly represent an echelon system, but there is no evidence of strong differential rock flowage akin to that in Northumberland; moreover, the exposures are largely concealed by drift.

The case of the sills is slightly more complex. In the Kilsyth-Croy area they appear to traverse powerful E.–W. faults without being thrown by them, or to change their horizon to an extent quite inconsistent with the measured throw of the dislocation. Thus in some cases they seem to be later than the faulting (30, pp. 154–155). There are, however, several examples in this district, besides numerous others in Fife, Stirlingshire, and the Lothians, of sills being thrown by E.–W. faults. When the relationship of the sills to the folding is considered the same contradictory evidence is encountered

in the Kilsyth-Croy district (30, pp. 155–156). At Barr Hill the sills seem to be later than the folding, while elsewhere they are definitely earlier. In the other districts they seem almost certainly to be earlier than the folding.

One may conclude therefore that both dikes and sills were more or less contemporaneous with the Permo-Carboniferous folding and faulting, but that the period of intrusion was probably somewhat prolonged.

Age.—If it be admitted that all the dikes and sills of the suite belong to the one period of intrusion, we can then fix their age almost beyond dispute. Tectonic considerations, as shown above, point to a Permo-Carboniferous age, but there is other evidence bearing on the point. Some of this is well summarized in the Glasgow Memoir (30, pp. 150–151).

The most important additional piece of evidence is the discovery by Professor Holmes in 1925 and confirmed by Dr. L. Hawkes of a pebble of undoubted Whin Sill type in the Permian Upper Brockram of the Eden Valley (loc. cit., pp. 532–534). An upper limit has thus been put to the age of the suite. The presence of fluorite in the Yellow Sands below the Magnesian Limestone of Yorkshire and its absence from the Coal Measures[1] is also taken to indicate that the mineralization which affected the Whin Sill was of Permo-Carboniferous age. Now in Scotland members of both the dike and sill phases petrographically identical with the Whin Sill are seen in many places to cut Coal Measures and a Permo-Carboniferous age may thus be assumed for the whole suite.

The evidence against a Permo-Carboniferous age is not strong. Mrs. I. F. Wallace[2] detected blocks of hypersthene-bearing quartz-dolerite in the ash vents of east Fife and the work of Mr. D. Balsillie has shown that some, at least, of these vents are of Lower Carboniferous age. Mr. Balsillie has pointed out that quartz-dolerites of Old Red Sandstone age are found among the sills of Angus in the neighbourhood of Dundee, and might also occur in the Lower Carboniferous intrusions; but the Angus examples are petrographically quite distinct from the blocks in the vents which are of identical

[1] The Permian strata of Scotland unfortunately lie outside the path of the two dike swarms.

[2] I. F. Wallace, Notes on the petrology of the agglomerates and hypabyssal intrusions between Largo and St. Monans. Trans. Geol. Soc. Edinburgh, 1916, vol. 10, pp. 357, 359, and 360.

ype to sills of our suite cutting Coal Measures. Furthermore, an .–W. quartz-dolerite dike at Kingask is seen to traverse an ash vent 1, p. 198). It seems probable, therefore, not that the suite is of other nan Permo-Carboniferous age, but rather that the volcanic activity f east Fife persisted throughout the Carboniferous System—a con- usion supported by the occurrence of vents piercing the Millstone rit and Coal Measures of the Leven coal basin.

Multiple injections.—The segregation of acid mesostasis into pink r grey contemporaneous veins and patches has long been known as ne of the most striking features of the quartz-dolerite members of ne suite; but the frequent occurrence of basaltic veins of similar mposition to the normal rock, but of distinctly later age, has been ss widely recognized. This basaltic phase may become quite im- ortant, as at Binny Craig in West Lothian (33), but is usually confined veins a few inches thick showing sharp junctions (which may or ay not be chilled) against the normal rock. The best examples re seen in the quartz-dolerite sill at Greenside Farm, Fife; the uartz-dolerite dike at Haggs Farm below Dalmahoy Hill, Midlothian; the tholeiite dike crossing the river at Tannadice in Angus; and other tholeiite dikes at Tullymet (two miles east of Ballinluig, erthshire) and Wolfhill (three miles east of Stanley Station, Perth- ire). At the four last localities the basaltic veins show well-marked illing against the normal rock and the dikes may consequently be onsidered as multiple.

3. Mineralogy.

Like all other rocks of tholeiitic magma-type the intrusions of the uite are of comparatively simple mineral composition. Plagioclase elspar, pyroxene, and iron-ore are in all cases amongst the dominant inerals, but any of the minor constituents such as micropegmatite, lass, hornblende, biotite, olivine, and chlorophaeite may become mportant locally. A description of the major constituents follows ogether with notes on some of the minor.

Felspars.—Plagioclase is always the most abundant constituent resent and is remarkably uniform in its characters throughout the uite. It forms long columnar crystals which in the normal rock ow a ratio of length to breadth about 4. The crystals have well- efined edges in the prism zone but irregular terminations. Carlsbad

and albite twinning are exceedingly common and pericline twinning rare. There are, however, numerous rectangular sections parallel to (010) which show no twinning.

The bulk of the felspar seems to be labradorite with a composition in the neighbourhood of $Ab_{50}An_{50}$, β being about 1·558 while the maximum symmetrical extinction given by sections normal to the albite lamellae is 27°. Zoning is always present, however, and the margins of the crystals often consist of a thin layer of oligoclase ($Ab_{80}An_{20}$). In several rocks, notably those of the dike in Corsiehill quarry near Perth and of the Lornty dike one mile north of Blairgowrie, distinctly more basic felspar was recorded with symmetrical extinction-angles up to 32°, β 1·563, and a composition about $Ab_{30}An_{70}$. In the case of the Lornty rock the basic felspar occurs as phenocrysts. No sign was seen in any rock of the anorthite phenocrysts recorded by Holmes (loc. cit., pp. 502–503) as occurring in the Whin Sill and its related dikes.

Besides the plagioclase described above a certain amount of alkali-felspar occurs in the quartz-dolerites. This may be either albite or orthoclase and occurs in the interstices between the plagioclase laths mainly in micrographic intergrowth with quartz. The micropegmatite is often so fine that it can only be distinguished under the highest powers of the microscope, but in other sills, particularly in those of the Denny-Stirling complex, it is relatively coarse. It is, on the whole, more prone to decomposition than the more basic plagioclase.

Pyroxenes.—The pyroxenes of the suite present many features of considerable interest. In the case of the tholeiites only one variety is found in an unaltered state, but in several of the quartz-dolerites three pyroxenes are found.

What may be termed the normal pyroxene of the suite—that is, the only fresh pyroxene of the tholeiites and the most abundant of the quartz-dolerites—is a pale-brown monoclinic variety standing roughly between the clinoenstatite-pigeonite and diopside-hedenbergite series. This pyroxene is of sub-ophitic habit (sub-doleritic of Krokström)[1] and in rocks where other pyroxenes occur it was invariably the last to crystallize, though in examples rich in micropegmatite it is sometimes idiomorphic. It is non-pleochroic and has an extinction-angle ($\gamma : c$) of 42°–44°. The optic axial angle (2V) of this variety was measured in slices from a considerable number of localities

[1] T. Krokström, Ophitic texture and the order of crystallization in basaltic magma. Bull. Geol. Inst. Univ. Upsala, 1933, vol. 24, p. 199.

both tholeiites and quartz-dolerites) with and without the universal stage. These measurements showed a variation between 45° in the base of the tholeiite from Corsiehill quarry to 52° in quartz-dolerite at Auchterarder Station. 48° was found to be a common value for 2V and it was further noted that there was very little zoning or variation of 2V in individual crystals. The pyroxene of the analysed tholeiite of Kinkell (36, p. 371) with 2V 48° gave the following values for the three refractive indices (measured by oils) α 1·699, β 1·708, γ 1·720. Sir John Flett (22, p. 304) made careful measurements of the value of 2E in the normal pyroxene of the quartz-dolerites of Sheet 32 and found it to vary between 80° and 82½°. These figures were confirmed absolutely by the author's measurements in the case of the rocks of the Ratho and West Craigs sills. In most cases the normal pyroxene is unaltered but when decomposition does take place it usually takes the form of alteration to carbonates from the centre outwards. Both simple and lamellar twinning parallel to (100) are common.

The other monoclinic pyroxene is quite different in appearance and is much rarer, occurring only in a few of the coarser quartz-dolerites, notably that of Ratho. It shows the pleochroism of hypersthene in faint tints, but $\gamma : c$ is 42° and $\gamma - \alpha$ about 0·021. 2V is variable but is distinctly lower than that of the normal variety. Some crystals are almost uniaxial, but values of 20°–30° are more common. The habit too is different, for it occurs as elongated prisms, sometimes showing sahlite striation, rather than sub-ophitic aggregates. It is invariably associated with rhombic pyroxene, which it greatly resembles when examined by ordinary light. This pyroxene is evidently a variety of pigeonite differing considerably in its optical properties from those described by Dr. T. Barth from the Hawaiian Islands.[1] It precedes the diopsidic pyroxene in crystallization, but is later than the rhombic pyroxene in the rare cases where the two are seen in contact. Though not so common as hypersthene it is found fairly commonly in the Edinburgh sills, the Bathgate Hill sills, and in the sill complex stretching from Stirling through Denny to Kilsyth. It has also been detected in dikes in Jura (24, p. 113) and Aberdeenshire (36, p. 326).

Rhombic pyroxene occurs in practically all the coarse quartz-dolerites and is represented by pseudomorphs in serpentine or chlorophaeite in many of the tholeiites. Like the pigeonite it is

[1] T. F. W. Barth, Amer. Journ. Sci., 1931, ser. 5, vol. 21, p. 377 [M.A. 4–508].

more liable to decomposition than the normal pyroxene. The fresh mineral shows pleochroism in pink and green tints of variable intensity. It is optically negative and the values for β and $\gamma - \alpha$ are usually about 1·700 and 0·012 respectively. Always the first of the pyroxenes to crystallize, it occurs as elongated prisms which occasionally attain a considerable length. In some of the tholeiites great difficulty was found in distinguishing pseudomorphs after hypersthene from those after olivine.

Iron-ore.—The chief iron-ore of the quartz-dolerites and tholeiites has long been considered to be a titaniferous magnetite or ilmenite in. In support of this view are its decomposition in places to grey leucoxene and its frequent skeletal habit. Writing of the Whin Sill however, Dr. J. A. Smythe (loc. cit., pp. 63–66) has adduced chemical evidence to show that ferric oxide may function under magmatic conditions as a ferrous ferrite ($FeO.Fe_2O_3$) and may thus join solid solutions with ilmenite ($FeO.TiO_2$). The same may be true of the Scottish rocks, but there is no evidence on this point. However that may be, the skeletal or even reticulate habit of the iron-ore is perfectly developed in some of the tholeiites, particularly in the beautifully fresh examples from the north of Kinkell quarry (36 pp. 371–372).

Another iron-ore of frequent occurrence, particularly in the quartz dolerites, is pyrite. In most cases it has a scaly habit and appears to be of aqueous and post-magmatic origin, being often concentrated along the contacts and joint-cracks.

Hornblende. In some of the coarser quartz-dolerites, e.g. the rock of Devonshaw quarry in Kinross-shire, cinnamon-brown hornblende occurs in parallel marginal intergrowth with the normal pyroxene. It shows moderate pleochroism in tints from clove-brown to almost colourless. $\gamma : c$ is 12–14°.

Biotite.—Dark red-brown biotite is of sparing occurrence in some quartz-dolerites as small flakes which appear in the main to be the product of reaction between the iron-ore and the magma.

Olivine.—No fresh olivine is found in either the quartz-dolerites or tholeiites of the suite, but pseudomorphs with the characteristic lozenge-shaped outline are frequently seen in the tholeiites and at the margins of some of the quartz-dolerite sills. The alteration product is usually serpentine, but in a few cases appears to be chlorophaeite. As mentioned above, it is often a matter of considerable difficulty to distinguish between pseudomorphs after olivine and hypersthene.

Chlorophaeite. Ever since the detection of chlorophaeite in the tholeiite of Dalmahoy by Drs. R. Campbell and J. W. Lunn,[1] its widespread occurrence in the suite under consideration has become increasingly evident. Not only is it found as a replacement product of olivine or hypersthene in both quartz-dolerites and tholeiites, but it appears to be in some cases a primary mineral of late consolidation, e.g. in the tholeiites of Dalmeny and Kinkell (36). In such instances it would appear that the iron was held up till a late stage and eliminated as chlorophaeite just before the consolidation of the residual glass (F. Walker, 36, p. 376; Campbell and Lunn).[2] A curious tholeiitic rock from an E.–W. dike at Lochearnhead has a groundmass consisting almost entirely of chlorophaeite.

Glass.—Unaltered glass occurs in only two tholeiites—those of Dalmeny and Kinkell (36). It is perfectly clear, of pale brown colour, and is crowded with microlites of plagioclase and pyroxene or lattices of ilmenite. The refractive index in each case is 1·495. In a few other tholeiitic dikes, notably those in the neighbourhood of Cortachy, Angus, and the example on the north face of Newton Hill, near Wormit, Fifeshire, alteration is only incipient and the glass slightly turbid. In the last tholeiite the glass is found lining vesicles which contain centres of quartz and calcite (pl. v, fig. 5). The plagioclase laths round these vesicles have a rough tangential arrangement. More often, however, the glass is completely decomposed to turbid reddish-brown material. It is often difficult to ascertain whether such decomposition products represent altered glass or cryptopegmatite. The fresh glass from the Kinkell tholeiite was isolated and analysed, the results being given below.

4. Petrological Characters and Classification.

With the exception of the coarser quartz-dolerites, all the rocks of the suite present much the same appearance in the hand-specimen. They are medium-grained and dark grey or black in colour when fresh, but assume a greenish tinge when decomposed. A characteristic reddish-brown crust forms on weathered surfaces. In the coarser quartz-dolerites the individual constituents can be made out with the unaided eye. Black, gleaming cleavage surfaces of pyroxene

[1] R. Campbell and J. W. Lunn, Chlorophaeite in the dolerites (tholeiites) of Dalmahoy and Kaimes Hills, Edinburgh. Min. Mag., 1925, vol. 20, pp. 435–440.

[2] R. Campbell and J. W. Lunn, The tholeiites and dolerites of the Dalmahoy syncline. Trans. Roy. Soc. Edinburgh, 1927, vol. 55, pp. 508–509.

are frequently conspicuous and occasionally take on a deceptive resemblance to biotite flakes. In such rocks the sporadic segregation of micropegmatite often gives rise to lighter coloured pink or white patches. The acid pink veins which traverse most of the quartz-dolerites rarely exceed an inch or two in breadth and are inconstant in their directions, as are the black basaltic veins found in both quartz-dolerites and tholeiites, though in some cases a tendency towards parallelism with the margins may be detected. Many of the quartz-dolerites are distinctly coarser than the normal Whin Sill type, but there seems to be a complete absence of the pegmatitic phase which is prominent in parts of the north of England intrusions.[1]

Quartz-dolerites.

Normal quartz-dolerite.—The microscopic characters of the quartz-dolerites have been so frequently and so fully described that little space will be devoted to them. They do not present much variation, on the whole, apart from changes in the proportion of micropegmatite. The presence of this constituent in any abundance has, however, a marked influence on the texture, for in these granophyric varieties both the plagioclase and the pyroxene crystals may become idiomorphic while there is a tendency towards elongation and curvature on the part of the latter mineral. Apatite is abundant in such rocks.

The proportion of hornblende and biotite, though never large, is also very variable and does not appear to have any connexion with the relative proportions of the other minerals. Professor W. W. Watts, writing in 'Ancient volcanoes of Great Britain' (9, vol. 1, p. 418), divides the quartz-dolerites into the Ratho type with relatively little mesostasis and the Bowden Hill type with much more. In the table of micrometric analyses given below the rocks of Hound Point (pl. v, fig. 1), North Queensferry, Laroch Hill, and Devonshaw are examples of the Ratho type (the type rock is unfortunately too much altered for accurate measurement), while the Bowden Hill type is represented by the rock of Kettlestoun quarry. The analysed rock of Auchterarder (pl. v, fig. 2) is of slightly different appearance to the foregoing and bears a close resemblance to parts of the Whin Sill. It is the freshest Scottish quartz-dolerite known to the author. The marginal proportions of the quartz-dolerite intrusions become

[1] S. I. Tomkeieff, A contribution to the petrology of the Whin Sill. Min. Mag., 1929, vol. 21, pp. 122–127.

tholeiitic in character through failure of the micropegmatite to crystallize, while the rock of the actual contact is usually of basaltic texture.

Acid veins.—The thin, light-coloured acid veins in the quartz-dolerites are nearly always much decomposed. Some of the freshest are seen under the microscope to consist of alkali-felspar (mainly orthoclase) and quartz occasionally in micropegmatitic intergrowth, but more often exhibiting microgranitic texture. Scraps of decomposed ferromagnesian minerals are of sparse occurrence and very rarely reveal themselves as elongated crystals of augite or hornblende.

Tholeiites.

The tholeiites closely resemble the quartz-dolerites in texture and mineralogical composition and differ from them microscopically only in the following particulars:

(1) No micropegmatite is found in the mesostasis of the tholeiites which is of glassy or cryptocrystalline nature.

(2) The earlier ferromagnesian minerals of the tholeiites are invariably decomposed.

For convenience of reference in this paper they may be divided into three types:

Bankhead type.—The tholeiites of Bankhead Cottages (at Dalmeny) and Kinkell quarry near Kirkintilloch (36) stand out from all others in the suite in virtue of their abundant unaltered glass and considerable proportion of chlorophaeite, which is of late crystallization and apparently primary. These characters link them with the Lower Carboniferous Dalmahoy type of tholeiite,[1] but this earlier group is distinctly more alkaline in character, and the type name cannot be therefore applied to the rocks of Dalmeny and Kinkell.

The type found in the northern portion of the working face of Kinkell quarry contains no chlorophaeite, but the glassy base is crowded with lattices of ilmenite. It is apparently unique in character. Both the Dalmeny and southern Kinkell rocks have been analysed. They differ markedly from all the Tertiary tholeiites in texture and chemical composition.

Corsiehill type (pl. v, fig. 3).—The rock of the 60-foot E.–W. dike of Corsiehill quarry north of Perth is very well preserved and proves

[1] R. Campbell and J. W. Lunn, The tholeiites and dolerites of the Dalmahoy syncline. Trans. Roy. Soc. Edinburgh, 1927, vol. 55, pp. 495–497.

under the microscope to be poor in glassy mesostasis but rich in monoclinic pyroxene. In texture it resembles the Ratho type of quartz-dolerite, but the early ferromagnesian mineral, which appears to be mainly hypersthene, is represented by pseudomorphs in serpentine. Olivine may also have been present originally, for a few lozenge-shaped pseudomorphs may be detected. This is the coarsest and most basic type of the tholeiites. It has been analysed and differs again from all the Tertiary types.

Newton Hill type (pl. v, fig. 5).—The E.–W. dike which runs along the north face of Newton Hill in north Fife is another well-preserved basic type. It is somewhat finer in grain than the Corsiehill type, and is distinctly richer in glassy mesostasis. In several ways it resembles the Bankhead type, for it contains a fair proportion of chlorophaeite, but the mineral is not primary and appears to represent olivine of early crystallization. In many examples of this type the place of chlorophaeite is taken by serpentine. The Craigmakerran type of tholeiite (38, p. 8) is practically identical to that of Newton Hill which, however, has been analysed.

Basalt Veins.

The black basaltic veins which occur in tholeiites and quartz-dolerites alike present considerable variety of texture. They are all porphyritic containing idiomorphic phenocrysts of labradorite, pyroxene, and sometimes olivine, but the groundmass may be a holocrystalline mass of minute plagioclase laths together with tiny augite granules and octahedra of magnetite, or it may be merely an indeterminate dark aggregate often almost opaque. The pyroxene is generally the normal variety of the coarser rocks, but in the basalt of Binny Craig (33, pp. 74–78) the phenocrysts sometimes contain a central rod of rhombic pyroxene. In this intrusion the basaltic phase is actually more abundant than the associated dolerite—a sharp unchilled junction occurring between the two modifications.

Hydrothermal Alteration.

Many of the more decomposed rocks have undergone the usual processes of chemical weathering, but in others there are distinct signs of hydrothermal action. This generally takes the form of albitization of the plagioclase and in such cases the ferromagnesian minerals are almost entirely altered—usually to calcite. In Fife-

shire, however, a different process is seen in many of the great quartz-dolerite sills which form the Riggin or backbone of the county from the Lomonds to St. Andrews. Here the plagioclase has undergone a patchy analcimization akin to that seen in teschenites of the Midland Valley. The zeolite also occurs in the interstices between the plagioclase laths, but is never found in association with micropegmatite. Though all the leucocratic constituents of these rocks are much decomposed, the ferromagnesian minerals, including even the rhombic pyroxene, have frequently escaped alteration almost completely. The author (32, pp. 15–16) has suggested that the analcimization is possibly due to liquors emanating from the adjacent teschenite sills which in this district are intruded into strata up to and including Coal Measures.

Contact Alteration.

The metamorphism produced by the quartz-dolerite and tholeiite intrusions is not particularly intense. In the Midland Valley, where the country-rock is usually sandstone or shale, local hardening takes place with the production of quartzite, porcellanites, or spotted shales. If the shale is carbonaceous the igneous rock has frequently been converted to the condition of white trap more or less completely (22, pp. 311–313). In some cases the hydrocarbons have been distilled off into neighbouring sandstones, rendering them black in colour.[1] Still other distillation phenomena may be noted. At Partridge Farm near Binny Craig (33, p. 75) vesicles in quartz-dolerite are filled with soft black petroleum which hardens on exposure to the air owing to loss of its volatile components, while in the quarry on the Ochil fault intrusion behind Tillicoultry some of the joint cracks in the dolerite were found by the author to contain a clear yellow petroleum jelly.

Where the country-rock consists of Lower Old Red Sandstones or conglomerates toughening and loss of colour is observed, but in the case of the andesites more interesting effects are sometimes seen. Thus in Corsiehill quarry Professor Shand[2] has recorded the presence of grossular amongst the contact lavas. Limestones have usually been recrystallized to saccharoidal marbles, and the Highland schist shows toughening without the production of many new minerals.

[1] D. Tait, Petroliferous sandstones in the Carboniferous rocks of Scotland. Trans. Geol. Soc. Edinburgh, 1928, vol. 12, pp. 90–104.

[2] S. J. Shand, Note upon crystals of grossularite from Corsiehill quarry. Trans. Perth Soc. Nat. Sci., 1908, vol. 4, pp. 210–212.

5. Distribution of Types.

The quartz-dolerites find their strongest development in the southern dike swarm and its associated sill complexes, including the great group stretching through Denny to Stirling. Here both Ratho and Bowden Hill types are found, the latter being particularly prominent among the sills of the Bathgate Hills. Tholeiites are distinctly rare as individuals in the thin southern group of intrusions, and are largely confined to the rapidly cooled margins of the quartz-dolerites. The rocks of Dalmeny and Kinkell quarry are notable exceptions.

In the northern swarm quartz-dolerites of Ratho type are abundant in the most southerly dikes and the associated sills of Fife and Kinross, but many of the sills in the former county exhibit the curious analcimization described above. North of Perth, however, tholeiites occur almost to the exclusion of quartz-dolerites in the northern swarm. They belong either to the Corsiehill or Newton Hill types, between which there is a gradational passage with increase of mesostasis. Neither type can be said to predominate in any one district.

The tholeiites in the Highland Border zone along western Strathmore have been referred to the Salen type by Dr. D. A. Allan (34, p. 87), but the author cannot confirm this determination and would place them rather in the Newton Hill type which is considerably less mafic. Neither can he agree with the inclusion of the Lornty rock by Drs. McLintock and Phemister[1] amongst the tholeiites of Brunton type, for his slides of this intrusion bear no resemblance to the type rock. It is closest to the Newton Hill type, from which it differs by being markedly porphyritic.

The dikes of Aberdeenshire are mainly tholeiitic in character, the analysed rock of Auchenbradie quarry (28, p. 164) being very similar to the Newton Hill type rock, as are the other tholeiites of this district.

The type names, 'Bankhead', 'Corsiehill', and 'Newton Hill' have been coined merely for convenience of reference in this paper. They are not intended for general application, as the literature of British tholeiites (particularly those of Tertiary age) is already overburdened by the multiplicity of types.

[1] W. F. P. McLintock and J. Phemister, On a magnetic survey over the Lornty dyke, Blairgowrie, Perthshire. Mem. Geol. Survey, Summary of Progress for 1930, part 3, p. 24.

6. Micrometric Data.

The mineral composition by volume of fourteen typical quartz-dolerites and tholeiites was measured with the aid of a Wentworth recording micrometer and the results are given in table I together with the average and maximum lengths of the plageoclase laths and the colour ratio. Apatite was not measured along with the other constituents. It occurs in proportions between 0·5 and 1·0 % in most cases.

Table I. *Mineralogical composition (by volume) and grain of quartz-dolerites and tholeiites.*

	Plagioclase.	Augite.	Hypersthene.	Iron-ore.	Mesostasis.	Maximum length of plagioclase, mm.	Average length of plagioclase, mm.	Colour ratio.
1.	54·6	23·4	3·1	7·9	10·0	1·5	0·8	35·4
2.	45·7	22·7	13·5	8·1	9·2	1·5	0·7	45·1
3.	45·0	24·8	11·7	6·2	12·3	2·5	1·0	42·7
4.	37·9	17·2	9·0	10·2	25·0	2·5	1·2	37·1
5.	45·2	22·6	17·3	6·8	8·1	2·0	1·0	46·7
6.	47·1	27·5	7·1	10·0	8·3	2·0	1·0	44·6
7.	41·6	23·5	12·4	8.2	14·3	2·2	0·9	44·1
Average	45·3	23·1	10·6	8·2	12·4	2·0	0·9	42·2
8.	46·1	27·7	4·8	9·2	12·2	2·0	1·0	41·7
9.	50·6	28·6	8·3	6·5	6·2	2·0	1·0	43·4
10.	44·6	29·2	6·7	6·4	13·1	1·2	0·6	42·3
11.	36·8	22·7	10·9	8·9	20·7	1·2	0·6	42·5
12.	28·3	22·4	7·0	10·8	31·5	2·0	0·9	40·2
13.	47·1	28·2	3·5	8·4	12·8	1·0	0·4	40·1
14.	38·7	26·3	5·7	9·1	20·7	1·0	0·5	41·1
Average	41·3	26·5	6·8	8·6	16·8	1·5	0·7	41·6
Total average	43·3	24·8	8·7	8·4	14·6	1·8	0·8	41 9

Quartz-dolerites.—

. Auchterarder Station, Perthshire (dike).
. Devonshaw quarry, Kinross-shire (sill).
. 1 mile south of Hound Point, Midlothian (sill).
. Kettlestoun quarry, W. Lothian (sill).
. Kinneston Craigs, Fife (sill).
. Laroch Hill, Argyllshire (dike).
. N. Queensferry quarry, Fife (sill).

Tholeiites.—

8. Auchenbradie quarry, Aberdeenshire (dike).
9. Corsiehill quarry, Perthshire (dike).
10. Craigmakerran, Perthshire (dike).
11. Dalmeny Station, W. Lothian (sill).
12. Kinkell quarry, Dumbartonshire (dike).
13. Lornty quarry, Perthshire (dike).
14. Newton Hill quarry, Fife (dike).

Nos. 1, 2, and 4 contain about 1·0 % of biotite and hornblende.

The figures for hypersthene in the tholeiites probably include some olivine in any cases.

The micrometric data given above show clearly that the quartz-dolerites and tholeiites are of very similar mineralogical composition, as are the dikes and sills. Such differences as do occur may probably be accounted for by varying physical conditions at the time of intrusion. Thus the tholeiites are of slightly finer grain than the quartz-dolerites and probably underwent more rapid cooling, which doubtless accounted for the glassy character of their base. In both quartz-dolerites and tholeiites there seems to be an antipathetic relationship between the proportions of mesostasis and pyroxene.

7. Chemical Data.

Four new chemical analyses were made for this paper—two of tholeiites, one of a quartz-dolerite, and one of the residual glass isolated from a tholeiite. They are given in table II together with the norms and specific gravities.

Table II. *New analyses.*

Analyses.

	(1).	(2).	(3).	(4).
SiO_2	49·36	47·39	47·69	66·80
TiO_2	1·97	2·17	4·17	0·18
Al_2O_3	13·77	11·81	11·25	12·10
Fe_2O_3	5·35	5·71	5·37	0·97
FeO	8·03	9·58	9·84	1·50
MnO	0·19	0·26	0·29	—
MgO	5·90	6·31	5·70	0·50
CaO	9·09	11·04	9·91	2·62
Na_2O	2·11	2·28	1·81	2·40
K_2O	0·98	0·66	0·84	4·20
H_2O+	1·31	1·24	1·83	5·75
H_2O-	1·18	1·25	0·62	3·00
P_2O_5	0·44	0·60	0·42	0·39
	99·68	100·30	99·74	100·41
Specific gravity ...	2·90	2·96	2·88	2·38

Norms.

	(1).	(2).	(3).	(4).
Quartz	6·5	2·3	7·7	30·7
Orthoclase	6·1	3·9	5·0	25·0
Albite	17·8	19·4	15·2	20·4
Anorthite	25·0	20·0	20·3	10·0
Diopside $CaSiO_3$ ...	7·3	13·0	10·9	0·1
Diopside $MgSiO_3$ ...	2·2	4·8	3·0	0·1
Diopside $FeSiO_3$ ...	4·6	7·6	6·8	0·1
Hypersthene $MgSiO_3$	5·0	5·0	3·8	1·2
Hypersthene $FeSiO_3$	10·1	8·2	7·5	1·3
Magnetite	7·9	8·4	7·9	1·4
Ilmenite	3·8	4·1	7·9	0·5
Apatite	1·0	1·3	1·0	1·0
Water	2·5	2·5	2·5	8·7
	99·8	100·5	99·5	100·5

(1) Quartz-dolerite, centre of dike, quarry at Auchterarder Station, Perthshire. Analyst, N. Sahlbom.

(2) Tholeiite, centre of dike, Corsiehill quarry, one mile west of Perth. Analyst, N. Sahlbom.

(3) Tholeiite, centre of dike, Newton Hill quarry, north face of Newton Hill, Wormit, Fife. Analyst, N. Sahlbom.

(4) Glass isolated from analysed tholeiite, Kinkell quarry, Kirkintilloch, Dumbartonshire (35, p. 372). Analyst, F. Herdsman.

All the existing superior analyses of Scottish quartz-dolerites, tholeiites, and their segregation veins are given in tables III and IV together with averages and other analyses for comparison. Any analysis the accuracy of which is at all questionable has been rejected.

TABLE III. *Chemical analysis of normal quartz-dolerites and tholeiites.*

	Quartz-dolerites.					
	(1).	(2).	(3).	(4).	(5).	(6).
SiO_2	49·36	48·50	47·75	49·87	49·08	48·02
TiO_2	1·97	2·00	2·17	2·96	2·37	3·36
Al_2O_3	13·77	13·56	13·98	14·61	12·70	13·03
Fe_2O_3	5·35	6·59	6·33	5·21	4·77	2·11
FeO	8·03	7·08	8·29	7·65	10·05	9·99
MnO	0·19	—	—	trace	—	trace
MgO	5·90	5·15	4·84	5·90	5·58	4·21
CaO	9·09	9·24	8·05	8·70	5·70	9·77
Na_2O	2·11	2·69	2·93	2·78	3·17	2·17
K_2O	0·98	0·89	0·70	0·66	1·31	0·49
H_2O+	1·31	3·21	3·27	1·23	3·86	4·27
H_2O-	1·18					1·05
P_2O_5	0·44	0·49	0·27	0·36	0·59	0·40
&c.	—	0·63	1·54	0·26	0·91	1·30
	99·68	100·03	100·12	100·19	100·09	100·17

	Tholeiites.					
	(7).	(8).	(9).	(10).	(11).	(12).
SiO_2	50·78	50·12	47·39	50·44	49·10	47·69
TiO_2	2·92	2·45	2·17	3·04	4·02	4·17
Al_2O_3	11·37	14·89	11·81	11·60	12·13	11·25
Fe_2O_3	3·27	2·78	5·71	6·29	4·61	5·37
FeO	10·72	9·96	9·58	6·16	8·92	9·84
MnO	0·26	trace	0·26	0·10	0·15	0·29
MgO	5·12	5·44	6·31	5·18	4·50	5·70
CaO	9·62	8·82	11·04	9·03	8·20	9·91
Na_2O	2·31	2·05	2·28	1·97	2·14	1·81
K_2O	0·70	1·25	0·66	1·33	2·10	0·84
H_2O+	0·86	0·90	1·24	2·70	2·50	1·83
H_2O-	0·77	1·00	1·25	1·59	1·02	0·62
P_2O_5	0·21	0·23	0·60	0·38	0·51	0·42
&c.	1·14	—	—	0·21	0·03	—
	100·05	99·89	100·30	100·02	99·93	99·74

TABLE IV. *Chemical analysis of segregation veins, average analyses and other analyses for comparison.*

	(13).	(14).	(15).	(A).	(16).	(17).
SiO_2	59·33	64·54	69·57	65·20	48·8	49·3
TiO_2	3·42	1·22	0·65	0·39	2·5	3·1
Al_2O_3	12·86	13·63	13·03	13·72	13·6	12·2
Fe_2O_3	1·88	0·22	0·98	3·63	5·1	4·7
FeO	6·46	4·83	3·59	3·72	8·5	9·2
MnO	0·14	0·20	—	—	—	0·2
MgO	2·09	1·25	1·06	1·01	5·3	5·5
CaO	3·74	2·31	1·56	2·79	8·4	9·4
Na_2O	5·13	5·21	4·57	5·22	2·6	2·1
K_2O	2·15	2·28	2·37	2·17	0·8	1·1
H_2O+	2·12	1·86	2·04	1·27	3·2	2·7
H_2O-	0·48	0·84		0·72		
P_2O_5	0·39	0·32	0·47	0·38	0·4	0·4
&c.	0·26	1·79	0·89	—	0·8	0·2
	100·45	100·50	100·78	100·22	100·0	100·1

	(18).	(B).	(C).	(D).	(E).
SiO_2	49·0	50·52	48·79	49·68	46·2
TiO_2	2·8	2·39	4·17	2·60	2·4
Al_2O_3	12·9	13·76	11·96	12·95	13·7
Fe_2O_3	4·9	3·87	2·51	3·47	2·1
FeO	8·9	8·50	12·10	10·10	9·2
MnO	0·1	0·16	0·21	0·20	0·2
MgO	5·4	5·42	5·60	5·69	9·6
CaO	8·9	9·09	10·15	10·09	9·8
Na_2O	2·4	2·42	2·40	2·27	2·6
K_2O	1·0	0·96	0·70	0·52	1·4
H_2O+	3·0	1·51	1·05	1·71	1·6
H_2O-		0·76		0·29	0·4
P_2O_5	0·4	0·26	0·37	0·33	0·5
&c.	0·5	0·69	—	0·04	0·2
	100·2	100·31	100·01	99·94	99·9

(1) Quartz-dolerite, centre of dike, quarry at Auchterarder Station, Perthshire. Analyst, N. Sahlbom. New Analysis.

(2) Quartz-dolerite, Hound Point sill, Dalmeny, West Lothian. Analyst, T. C. Day. Quoted from T. C. Day, Trans. Geol. Soc. Edinburgh, 1928, vol. 12, p. 85.

(3) Quartz-dolerite close to segregation vein at same locality. Analyst, T. C. Day (loc. cit.).

(4) Quartz-dolerite, North Queensferry sill, Fife. Analysts, J. B. Harrison and Reid. Quoted from U.S. Geol. Survey Prof. Paper 99, 1917, p. 649.

(5) Quartz-dolerite, Ferrytoll quarry, North Queensferry sill. Analyst, T. C. Day (loc. cit.).

(6) Quartz-dolerite sill at Kettlestoun quarry, Bathgate Hills, West Lothian. Analyst, G. S. Blake. Quoted from (15, p. 147).

(7) Tholeiite, dike in Auchenbradie quarry, Insch, Aberdeenshire. Analyst, G. Radley. Quoted from (28, p. 164).

(8) Basaltic tholeiite, Binny Craig sill, West Lothian. Analyst, W. H. Herdsman. Quoted from (33, p. 78).

(9) Tholeiite, dike in Corsiehill quarry, Perthshire. Analyst, N. Sahlbom. New Analysis.

(10) Tholeiite, sill in railway cutting, Dalmeny, West Lothian. Analyst, L. Jakob. Quoted from (36, p. 370).

(11) Tholeiite, dike in Kinkell quarry, Kirkintilloch, Dumbartonshire. Analyst, L. Jakob. Quoted from (36, p. 372).

(12) Tholeiite, dike in quarry on north face of Newton Hill, Wormit, Fife. Analyst, N. Sahlbom. New Analysis.

(13) Felspathic quartz-dolerite, sill at Kettlestoun quarry, Bathgate Hills, West Lothian. Analyst, G. S. Blake. Quoted from (15, p. 147).

(14) Segregation vein (blue band) in quartz-dolerite, sill at Caribber quarry, Bathgate Hills, West Lothian. Analyst, G. S. Blake. Loc. cit. supra.

(15) Segregation vein in quartz-dolerite, sill at Ferrytoll quarry, North Queensferry, Fife. T. C. Day, Analyst. Quoted from T. C. Day, Trans. Geol. Soc. Edinburgh, 1928, vol. 12, p. 85.

(A) Felsitic vein in Whin Sill, Alnwick Moor, Northumberland. Analyst, J. I. Tomkeieff. Quoted from Min. Mag., 1929, vol. 22, p. 110.

(16) Average Scottish quartz-dolerite.

(17) Average Scottish tholeiite.

(18) Average of Scottish quartz-dolerites and tholeiites.

(B) Average Whin Sill magma. Quoted from A. Holmes and H. F. Harwood (loc. cit., p. 539),

(C) Basalt, Holmatindur, Iceland. Analyst, H. F. Harwood. Quoted from A. Holmes, Min. Mag., 1918. vol. 18, p. 192.

(D) Average Deccan basalt. Quoted from A. Holmes, Min. Mag., 1928, vol. 21, p. 539.

(E) Average of three analyses of basalt of Dalmeny type taken from The Geology of north Ayrshire, Mem. Geol. Survey, 1930, p. 106.

The chemical data, like the micrometric, show that, apart from segregation veins and patches, there is little variation in the composition of the normal quartz-dolerites and tholeiites of Scotland. The Scottish tholeiites have a slightly lower alumina percentage than the quartz-dolerites and seem to be a little richer in potash, but there the difference ends. Indeed the essential similarity of the two types is far more striking than these slight variations. The new analyses agree well with those published previously.

The average chemical composition of the Scottish rocks is slightly more basic than that of the average Whin Sill type in the north of England, but again the strong resemblance is much more marked than the difference. The quartz-dolerite of Auchterarder Station especially, which is very similar microscopically to the Whin Sill type, shows an equally close chemical resemblance. It seems, therefore, certain

that the north of England intrusions and the Scottish quartz-dolerite and tholeiites are co-magmatic, the conclusions reached by the field evidence being firmly supported by the chemical data.

The analyses of the Scottish rocks may be well matched by the average Deccan basalt and by a plateau basalt from Iceland.

All the Scottish quartz-dolerites and tholeiites appear to be just over the saturation point with silica, the residue, when fresh, being in all cases siliceous. Even in the most basic analysis—that of Corsiehill—2·3 % of normative quartz was recorded.

The chemical resemblance of the quartz-dolerites and tholeiites of Scotland to those of the Whin Sill group of the north of England extends to the acid segregation veins and also to the later basaltic injections which have in both areas practically the same composition as the normal rock. In the case of the acid veins the close resemblance may be seen by comparison of analyses 14 and A which show excellent agreement.

The chemical composition of the residual liquid.

In recent years there has been a certain amount of discussion as to the chemical composition of the residual liquids of basalts and dolerites. Dr. C. N. Fenner[1] has expressed the opinion that the micrographitic and myrmekitic intergrowths found in many doleritic intrusions are the result of chemical action of late hydrothermal solutions and cannot be regarded as primary constituents of the magma. He has stated further that the low refractive indices recorded for the residual glasses of basalts of tholeiitic composition are due to the presence of borates, fluorides, and phosphates, and that they are rich in iron oxide and not of dacitic composition as the figures would indicate.

In describing two tholeiitic members of the suite now under consideration, the author (36, pp. 374–376) gave reasons for opposing this view. He showed that the residual glass of these tholeiites had a refractive index (1·495) corresponding to that of rhyolitic obsidian, that the glass contained no noteworthy proportions of phosphates and fluorides, and that the presence of the small percentage of B_2O_3 actually found in the glass would probably raise the index rather than lower it. The view of Dr. Fenner that iron in

[1] C. N. Fenner, The crystallization of basalts. Amer. Journ. Sci., 1929, ser. 5, vol. 18, pp. 239–243 [M.A. 4–507].

concentrated in the residual liquids of such magmas was, however, confirmed by the detection of chlorophaeite and ilmenite of late crystallization. In a later article Dr. Fenner [1] criticized the author's result on the grounds that the rocks studied were not volcanic but deep-seated, and that the proportion of glass was relatively large. He apparently inclined towards the view that the micropegmatite of the Scottish quartz-dolerites was probably of hydrothermal origin, and that the low refractive index of the glass might still be due to the presence of halides, since the evidence adduced by the author on the point was regarded by him as insufficient.

It seemed advisable, therefore, to isolate the glass from one of the analysed tholeiites and to have a chemical analysis made of this material. After repeated separations by heavy liquids, checked at each stage by microscopic examination, an unaltered glass was obtained from the southern Kinkell rock containing less than one per cent. of impurities (mainly plagioclase and chlorophaeite). This was analysed by Mr. F. Herdsman and the results are given in the table of new analyses (p. 150). They show clearly that the glass is, as the low refractive index would indicate, highly siliceous, the percentage of SiO_2 being 72·1 if the analysis is calculated as water-free. This value is actually higher than that in the most siliceous analysis, no. 15 on p. 152, that of a pink segregation vein. In other respects the two analyses show moderate agreement. It may be therefore considered as definitely proved that the residual liquids of members of the suite under consideration are highly siliceous and might be expected accordingly to yield micropegmatite upon crystallization. The glass from the rock of the north part of the quarry has exactly the same refractive index as that isolated, but is crowded with lattices of ilmenite crystals and might for this reason be regarded as rich in iron. The author maintains, however, that the bulk of the iron is removed as chlorophaeite or iron-ore just before the solidification of the glass. In the analysis of the glass the percentage of total iron oxides, even if calculated as water-free, amounts to less than two-thirds of the corresponding percentage in the most siliceous segregation vein. The refractive index of the residual glass is then a reliable guide to its chemical composition in the case of these tholeiites, and it is unnecessary to invoke the aid of occluded halides, borates, and phosphates to account for the low refractive index. Moreover, if

[1] C. N. Fenner, The residual liquids of crystallizing magmas. Min. Mag., 1931, vol. 22, pp. 539–560.

these conclusions are applied to the co-magmatic quartz-dolerites which are of very similar chemical and mineralogical composition, there is every reason to believe that their micropegmatite is of late magmatic origin and not due to hydrothermal reactions as Dr. Fenner has suggested.

Dr. Fenner has objected that the tholeiites examined by the author contained a relatively large proportion of glass as opposed to the basalts examined by him (C.N.F.). It may be noted, however, that the glass of these tholeiites is, like the micropegmatite of the quartz-dolerites, notoriously capricious in its distribution, and that at both Dalmeny and Kinkell, not to mention numerous other localities where the glass is more or less decomposed, specimens may be found in which the proportion is quite small. With regard to Dr. Fenner's criticism that the tholeiites in question are deep-seated hypabyssal rocks, it should be observed that their grain is no coarser than that of many basalt lavas and that the mere fact that the residual liquid solidified as glass is evidence that cooling was much more rapid than is consistent with deep-seated conditions.

Confirmation, however, was obtained of Dr. Fenner's contention that there is a tendency towards concentration of the iron in the residual liquid of basalt as crystallization proceeds, for the Fe : MgO ratio in the residual glass of the Kinkell tholeiite is considerably greater than that in the normal rock.

8. Relationship of the Suite to Carboniferous volcanic Activity.

The exact connexion between the rocks of the suite and the Carboniferous volcanicity of southern Scotland is doubtful. Showing remarkably little variation in chemical composition, the quartz-dolerites and tholeiites are clearly of tholeiitic magma-type. The Carboniferous (and Permian) igneous rocks, on the other hand, are all of olivine-basalt magma-type. The micro-porphyritic Dalmeny type of olivine-basalt very probably represents the parental magma, in view of its early occurrence, uniform composition, and extended distribution (both lateral and vertical).

Comparison of analyses nos. (18) and (E) shows that the quartz-dolerite magma is poorer in alkalis than the relatively basic Dalmeny type of olivine-basalt (or any other widespread type of Carboniferous olivine-basalt) and cannot, therefore, have been derived from this magma by any process of crystallization-differentiation or gaseous

ansfer. Nor can the derivation be effected, as was suggested by
. G. W. Tyrrell (21, p. 365), by simple assimilation, for the con-
ruction of an addition and subtraction diagram proves that both
e most siliceous material which could be added or the least siliceous
btracted, to give the quartz-dolerite type, have compositions far

Fig. 2. Sketch-map showing relationship of quartz-dolerite and tholeiite dikes to the Carboniferous volcanic rocks.

moved from those of any known igneous or sedimentary rocks or
ixture thereof. Selective assimilation of silica and iron oxide
companied by loss of magnesia might provide a solution to the
oblem, but no evidence on this point can be advanced. It is con-
ivable, however, that such a process might have taken place if the
rboniferous olivine-basalt magma remained in contact with the
wer layers of the 'sial' for a prolonged period. If this was the
se, the Permo-Carboniferous earth-movements must have opened
nduits to the contaminated material of the upper 'sima', allowing
to work upwards, though not, apparently, to the surface. In this
nnexion the restriction of the tholeiite magma-type to the 'sial'

continental blocks and its absence from oceanic islands[1] is, perhaps, significant.

The sketch-map (text-fig. 2) shows that the distributions of the two suites have no close link, especially if the quartz-dolerite sills be excluded on the ground that they merely represent the lateral spread of material from the dikes controlled partly by planes of weakness in the sedimentary series and partly by the hydrostatic pressure exerted by the superincumbent rock-column. It will be seen, indeed, that the dike swarms bear no distributional relationship to any of the centres of Carboniferous volcanicity. Their occurrence appears to be controlled rather by the powerful Permo-Carboniferous earth-movements, as might be expected.

The differentiation of the two magma-types followed the course so clearly outlined by Dr. W. Q. Kennedy (loc. cit.), the alkaline differentiates of the Carboniferous olivine-basalt contrasting strongly with the calcic and granophyric products of the quartz-dolerite suite.

9. Rocks of doubtful affinities.

In Morvern the work of Mr. A. G. MacGregor and Dr. W. Q. Kennedy[2] has revealed the presence of a series of bosses of quartz-dolerite which are elongated in an E.-W. direction. These are coarse-grained rocks resembling the quartz-dolerites of the Midland Valley and they may belong to the same suite. They have brought about very considerable metamorphism of the country-rock.

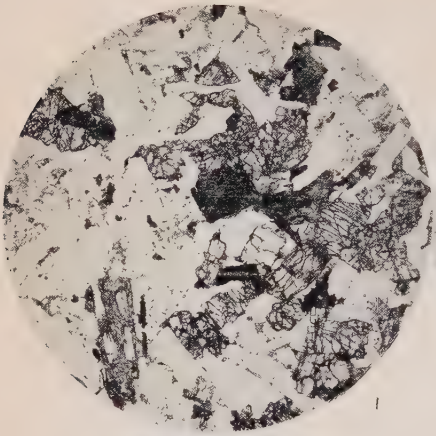
There are also the Milngavie sills near Glasgow to be considered (as well as a few sills near Edinburgh) which carry neither olivine, hypersthene, nor acid mesostasis. They show affinities with both the quartz-dolerite and teschenite suites, but the nature of the pyroxene—a brownish-purple variety with 2V about 60°—links them more closely with the latter group. No dike of this type has been recorded.

10. Summary.

The E.-W. dikes of quartz-dolerite and tholeiite in Scotland and the related sills show marked resemblances, both chemical and mineralogical, to the Whin Sill in the north of England. They appear to belong to the same period of intrusion, which is roughly coeval

[1] W. Q. Kennedy, loc. cit., p. 249.

[2] A. G. MacGregor and W. Q. Kennedy, The Morvern-Strontian granite. Mem Geol. Survey, Summary of Progress for 1931, part 2, p. 105.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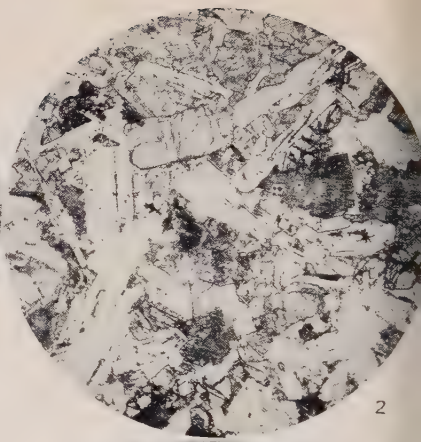
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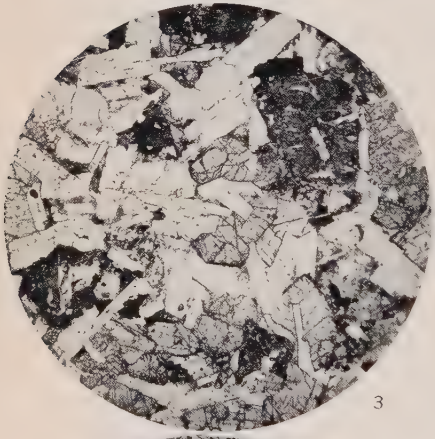
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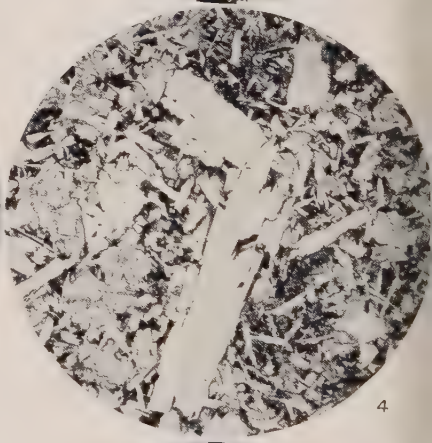
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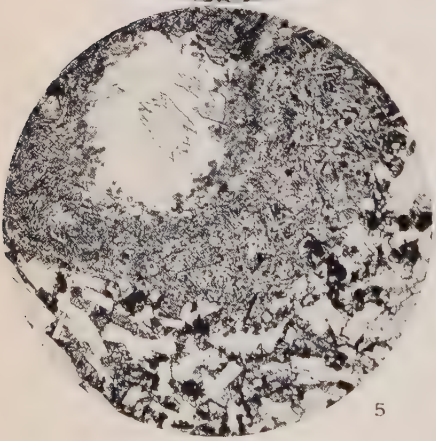
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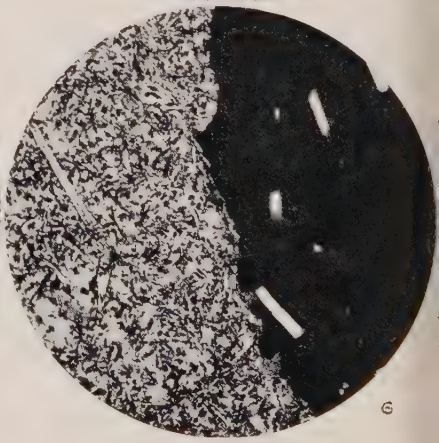
6

F. WALKER : QUARTZ-DOLERITES AND THOLEIITES

ith the Permo-Carboniferous folding and faulting. Chemical analyses an unaltered residual glass in one of the tholeiites shows it to be ghly siliceous, and there is therefore no reason for considering the icropegmatite of the very similar quartz-dolerites to be other than agmatic. It is suggested that the suite may have arisen through ild contamination of the parental Carboniferous olivine-basalt agma by prolonged contact with the 'sial'.

Acknowledgments.—The author is greatly indebted to the following ntlemen for much helpful discussion of the paper and in some cases r the loan of slides or the gift of material for sectioning:—Professor . A. Daly, Professor A. Holmes, Dr. W. Q. Kennedy, Professor E. S. arsen, Mr. John Ritchie, Dr. H. H. Thomas, Mr. S. I. Tomkeieff, r. T. F. W. Barth, and Dr. C. N. Fenner.

Grateful acknowledgment is also expressed to the Carnegie Trust r the Universities of Scotland for grants in aid of the chemical and ptical parts of this research.

Explanation of Plate V.

Quartz-dolerites and tholeiites.

Fig. 1. Quartz-dolerite, centre of sill, Hound Point, West Lothian. Ordinary ght, ×15. Laths of plagioclase show subidiomorphic relationship with diopsidic roxene. A few crystals of titanomagnetite are conspicuous, and a prism of persthene occurs in the bottom left-hand quadrant. A little turbid micro-egmatite fills the interstices between the felspar.

Fig. 2. Quartz-dolerite, centre of dike, Auchterarder Station, Perthshire. rdinary light, ×16⅔. A similar rock to fig. 1, but with texture closer to the ormal rock of the Whin Sill.

Fig. 3. Tholeiite, centre of dike, Corsiehill quarry, Perthshire. Ordinary ght. ×16⅔. Similar to figs. 1 and 2, but the place of micropegmatite is taken y devitrified glass, and that of hypersthene by conspicuous pseudomorphs in erpentine.

Fig. 4. Tholeiite, quarry at west end of dike, Lornty, Perthshire. Ordinary ght, ×16⅔. Phenocrysts of basic labradorite are conspicuous in a groundmass f labradorite laths, sub-ophitic pyroxene, titanomagnetite, and mesostasis.

Fig. 5. Tholeiite, quarry in dike, on north face of Newton Hill, Fife. Ordinary ght, ×15. Part of a circular vesicle with a glassy margin and a centre of uartz and calcite fills most of the field. The remainder consists of plagioclase ths, sub-ophitic pyroxene, titanomagnetite, and devitrified glass.

Fig. 6. Basalt vein in quartz-dolerite sill. Greenhill Farm, Fife. Ordinary ght, ×16⅔. A black basaltic vein containing a few phenocrysts of plagioclase seen to be chilled against a fine-grained decomposed quartz-dolerite or tholeiite.

Fictitious occurrences of iron silicide (ferrosilicon).

By L. J. Spencer, M.A., Sc.D., F.R.S.
Formerly Keeper of Minerals in the British Museum.

[Read November 9, 1933.]

FERROSILICON is occasionally found under circumstances that suggest that it is a natural mineral. Twice during the past quarter of a century it has been described as a *new* mineral, and the error was detected only after preliminary accounts had been published. It has also at times been thought to be meteoric. A supposed meteoric iron from North Carolina was described by C. U. Shepard in 1859 as composed of a material to which he gave the name 'ferrosilicine'.

The following notes collected during several years contain nothing new. They are merely brought together to serve as a warning against an error that may recur.

On several occasions between 1924 and 1929 Mr. H. N. G. Cobbe, a consulting mining engineer, sent to me for identification rounded pieces of a metallic substance that had been picked out from the concentrates of the gold dredgers on rivers and creeks in British Guiana. After some trouble we were able to match these with the nodules of ferrosilicon sometimes present in commercial calcium carbide. Evidently the spent carbide from the acetylene flares was emptied out into the river to be collected again by the dredgers.

For comparison, Mr. Cobbe obtained samples from the works of Messrs. Allen Liversidge. Another sample was obtained through Prof. V. M. Goldschmidt from the calcium carbide works of the Aktieselskabet Meraker Smelteverk at Kopperå in Norway. A larger broken fragment (67·23 grams), found in a large container of carbide used for acetylene welding, was given by Mr. R. G. Thomson of Birmingham.

This material usually has the form of more or less spherical pellets up to a centimetre in diameter; but some irregular pieces up to $4\frac{1}{2}$ cm. across, broken from larger slabby masses, were seen. It is

eel-grey to tin-white with a bright metallic lustre. A bronze-llow tarnish is sometimes shown; but there is no rust. It is very rd (H. $6\frac{1}{2}$) and brittle, and is readily powdered with a hammer. ie fracture is uneven. The specific gravity is variable, 5·8–6·8, e partly to cavities in the mass. Some of these cavities are bbles with smooth surfaces, and others are partly filled with athery and platy agregates of minute tetrahedra. The magnetic aracter is also variable: some pieces are attracted by a magnet, ile others are not. Some pieces are slightly attacked by hydro-loric acid, but usually they are not affected even by aqua regia. ie material is decomposed by hydrofluoric acid or by fusion with ustic soda. An approximate analysis of a pellet from British iana gave Fe 65, Si 35 % corresponding nearly to the formula Si.

Nodules of ferrosilicon occurring as an impurity in commercial lcium carbide were described by Vivian B. Lewes[1] in 1898 and th some further details in his book 'Acetylene', in 1900. He dis-nguished two kinds: (1) grey, sp. gr. 3·5–5·8, non-magnetic, not idized before the blowpipe; (2) steel-grey, sp. gr. 6·3–6·8, strongly agnetic, slowly oxidized by air and water. His analysis (of which nd not stated) gave Fe 58·07, Si 30·76, Ca 2·65, Al 3·01, Mg 0·64, &c. 4·87 = 100·00. Analyses quoted by J. H. Vogel[2] show the llowing extremes: Fe 62·7–82·1, Si 16·3–33·5, C 0·1–2·2.

'A supposed new mineral', said to have been found in the basalt f County Antrim, was briefly described in 1909 as a compound of on, silicon, and carbon. Mention was made of the fact that when e material was powdered, or even scratched, it emitted an odour ke that of acetylene prepared from commercial calcium carbide. he finding of this material in basalt could not be confirmed, and a ter note admitted that it was very probably an artificial product.[3] he characters, so far as stated, agreed with those of ferrosilicon.

Another 'new mineral?'[4] was found in 1911 as small pellets on ne separating tables at the Kimberley diamond mines in South frica. It was slightly magnetic, with sp. gr. 6·7, H. '6–9', and ontained Fe 71·39, Si 20·03, C 8·41 %. When broken, it gave off

[1] V. B. Lewes, Journ. Soc. Chem. Industry, London, 1898, vol. 17, p. 532; Acetylene', London, 1900, p. 331.

[2] J. H. Vogel, Handbuch für Acetylene, Braunschweig, 1904, p. 13.

[3] R. J. Moss and H. J. Seymour, Nature, London, 1909, vol. 81, p. 518; 1910, ol. 82, p. 280.

[4] J. R. Sutton, A new mineral?, Nature, London, 1911, vol. 87, p. 314.

a strong smell of carbide. A further examination[1] proved the identity of this material with the pellets of iron carbide and iron silico-carbide found in commercial calcium carbide. At that period the blue ground from the diamond mines was disintegrated by the action of the weather, for which purpose it was spread out on extensive 'floors'. To prevent any thefts of diamonds these floors were surrounded by a barbed wire fence and at night lit by acetylene flares. The spent carbide was no doubt emptied out on the spot and so got mixed with the blue ground.

A magnetic nodule found near Renison Bell in Tasmania, which was thought to be perhaps a meteorite, when shown to Mr. G. W. Card, Curator of the Mining and Geological Museum at Sydney, was at once recognized by him as a calcium carbide residue—a pitfall that he had met before.[2]

An alleged meteorite from Greece was offered to the British Museum in 1929. It weighed 140 grams and an analysis made in Athens showed Fe 74·03, Si 19·76, Ni 0·10 %, sp. gr. 7. When received, it was found to have the characters of the ferrosilicon from calcium carbide.

Crystallized compounds of iron and silicon are Fe_3Si (cubic; containing Si 20·0 %), FeSi (tetrahedral-cubic; Si 33·3 %), and $FeSi_2$ (tetragonal; Si 50·0 %). Other compounds have been suggested and there is a continuous series of alloys Fe–Si. Ferrosilicon containing about 15 % Si was made commercially in the blast furnace, and more recently higher grades containing 25–95 % have been made in the electric furnace. These are used in the manufacture of steel. Some of them are unstable, especially that containing about 56 % Si, which may decompose with explosive violence, and shipwrecks have been so caused. The most stable is FeSi, which is not attacked by acids (except HF). This retains its metallic appearance when exposed to the weather, and for this reason it would be likely to be found in odd situations.

Calcium carbide was first manufactured commercially in 1895, and it will be noticed that the fictitious occurrences of ferrosilicon men

[1] B. de St. J. van der Riet, A supposed new mineral from Du Toitspan Kimberley. Trans. Roy. Soc. South Africa, 1912, vol. 2, Proc. pp. xxix–xxx; Nature, London, 1911, vol. 88, pp. 166–167.

[2] H. Conder, Geological pitfalls. Industrial Australian and Mining Standard, 1926, vol. 76, p. 6; reprinted in Mining Magazine, London, 1926, vol. 35, p. 190.

[3] E. S. Greiner, J. S. Marsh, and B. Stoughton, The alloys of iron and silicon, New York and London, 1933, p. 66.

tioned above are all subsequent to that date, except the 'ferrosilicine' of C. U. Shepard[1] in 1859. Two analyses of this gave Fe 84·00, Si 13·57, C trace, P 1·31; and Fe 87·10, Si 10·60, C 0·40, P trace; sp. gr. 6·745. C. F. Rammelsberg[2] determined Si 15·7, and he concluded that the material was a white cast iron of poor quality.

FIG. 1. Parallel grouping of tetrahedral-cubic crystals of iron silicide (FeSi). ×4.

Rutherfordton, where the specimen was found, was the centre of an iron mining district and there were furnaces in the neighbourhood. A fragment of the specimen, acquired by the British Museum from C. U. Shepard in 1860, is strongly magnetic and on the steel-grey fractured surface has quite the appearance of ferrosilicon. This, as well as some other pseudo-meteorites,[3] must then be referred to blast

[1] C. U. Shepard, Examination of a supposed meteoric iron, found near Rutherfordton, North Carolina. Amer. Journ. Sci., 1859, ser. 2, vol. 28, pp. 259–270.
[2] C. F. Rammelsberg, Journ. Prakt. Chem., 1862, vol. 85, p. 88.
[3] L. J. Spencer, Pseudo-meteorites. Nat. Hist. Mag. (British Museum), 1931, vol. 3, pp. 44–56 [Min. Abstr., vol. 5, p. 9].

furnace products. Some of these have been produced accidentally, often in blast furnace 'bears'.[1] They are materials likely to be carried about by persons with magpie propensities, and when lost to be found again in strange situations.

A crystallized 'silico-ferro-manganese' was described in this Magazine[2] in 1903. This is triclinic and has the composition Fe 67·40, Mn 20·10, Si 10·50, C 1·63, P 0·17, S trace. It belongs to the orthorhombic and triclinic series $(Fe,Mn)_3(C,Si)$, which include ferro-manganese and Spiegeleisen. These also have masqueraded as meteorites.

The crystallized furnace products which I described in 1903 were mostly supplied by the late Dr. J. E. Stead. Subsequent to that date he sent, in 1906, a beautifully crystallized specimen of ferro-silicon (FeSi), which may be briefly described in this place. This is tetrahedral-cubic[3] and is identical with the main part of the material found in calcium carbide residues. This specimen (fig. 1; B.M. 1906,394) shows over areas up to $2\frac{1}{2} \times 1\frac{1}{2}$ cm. a strictly parallel grouping of large numbers of sharply developed regular tetrahedra. These measure 1–2 mm. along the edge and show brilliant facets with sunken, step-like surfaces. They build up larger, but distorted and flattened, tetrahedra which are irregularly grouped together. Another more compact specimen (B.M. 1906,395) shows feathery aggregates of minute tetrahedra crystallized on the surface and in a cavity in the mass. This material is steel-grey with bright metallic lustre and strongly magnetic. It is very hard (H. $6\frac{1}{2}$) and brittle, sp. gr. (D^{24}_4) 6·46, and is not attacked by acids. It came from a melt containing 26 % Si.

[1] 'Bears' are masses of metal (sometimes weighing hundreds of tons) found in the foundations of dismantled furnaces, and represent the accumulation of molten metal that has corroded through the furnace lining. These also have often been thought to be 'meteorites'.

[2] L. J. Spencer, Crystalline forms of carbides and silicides of iron and manganese ('ferro-manganese', &c.). Min. Mag., 1903, vol. 13, pp. 296–302.

[3] FeSi was first determined to be tetrahedral-cubic by A. de Schulten, Compt. Rend. Acad. Sci. Paris, 1911, vol. 152, p. 1107, and this has since been confirmed by X-ray examination by G. Phragmén (1923, 1926; M.A. **3**–337) and H. Möller (1930; M.A. **4**–361, **4**–460).

A critical review of the data for a revision of the enstatite-hypersthene series.

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[Communicated by Prof. H. H. Read; read March 14, 1935.]

AT the suggestion of Professor H. H. Read the optic axial angle and the refractive index γ were measured in four hypersthenes rom Aberdeenshire norites. As the values obtained suggested that ne minerals were iron-rich, it was decided to have chemical analyses ade. These and the optical data are set out in table I below. At ne same time the literature has been searched for analyses and ptical data of enstatites and hypersthenes, in order to supplement hose used by A. N. Winchell in his diagram of variation of the roperties of the series.[1] The references given by Winchell have een examined, and it is found that some of the data is not reliable. curve embodying what are considered to be superior values of 2V nd γ is presented (fig. 1).

Hypersthene from Aberdeenshire.

Specimen (*a*) came from the norite of the Arnage mass, described y H. H. Read;[2] it takes the form of small (1·0 mm. diameter) sub-edral grains, showing prismatic cleavages and a distinct pleochroism. t is accompanied by green hornblende and brown biotite, which ometimes show a reaction relationship to it, and is set in a base of lagioclase with a little quartz.

Specimen (*b*) was obtained from a 'micro-noritic' plagioclase-ypersthene xenolith in the norite of the Haddo mass.[3] The hyper-thene forms clear, pale green to pink, rounded grains, about 0·07 mm. iameter, set in a base of plagioclase felspar, and makes up about 0 % of the volume of the xenolith.

[1] A. N. Winchell, Amer. Journ. Sci., 1923, ser. 5, vol. 6, p. 504 [M.A. 2-219]; nd Optical mineralogy, 3rd edit., 1933, pt. 2, p. 218.

[2] H. H. Read, Quart. Journ. Geol. Soc. London, 1923, vol. 79, p. 454.

[3] H. H. Read, Quart. Journ. Geol. Soc. London (in the press).

TABLE I. *Hypersthene from Aberdeenshire.*

	(*a*)	(*b*)	(*c*)	(*d*)
SiO_2	51·96	49·52	49·85	45·98
TiO_2	0·37	0·59	0·44	0·55
Al_2O_3	0·01	3·60	2·82	2·95
Fe_2O_3	3·91	nil	1·90	6·27
FeO	19·48	26·47	27·41	28·95
NiO	nil	trace	0·01	trace
MnO	0·39	0·46	0·63	0·30
MgO	17·10	16·65	15·57	12·80
CaO	5·96	1·18	0·83	0·67
Na_2O	nil	0·12	0·13	0·03
K_2O	0·18	0·18	0·19	0·24
$H_2O(+110°\,C.)$ ...	0·28	0·79	0·39	1·01
$H_2O(-110°\,C.)$ ...	0·08	0·15	0·08	0·13
P_2O_5	0·51	0·30	trace	0·17
	100·23	100·01	100·25	100·05

Analyst, A. W. Groves.

D_{20}^{20}	3·49	3·53	3·56	3·58
$\gamma_{Na}(\pm 0·001)$ ...	1·703	1·730	1·731	1·735
$2V(\pm 1°)$	71°	53°	55°	67°
Pleochroism: α	pale red-brown	pale pink	pink	deep red
Pleochroism: β	yellow-green	pale yellow-green	yellow-green	yellow-brown
Pleochroism: γ	green	pale green	pale green	deep green

(*a*) Hypersthene, from norite of the Arnage mass, Railway Bridge Croft, Arnage, Aberdeenshire.

(*b*) Hypersthene from 'micro-noritic' xenolith in norite of the Haddo mass, Quilquox, Methlick, Aberdeenshire.

(*c*) Hypersthene from norite enclosing xenoliths, Quilquox, Methlick, Aberdeenshire.

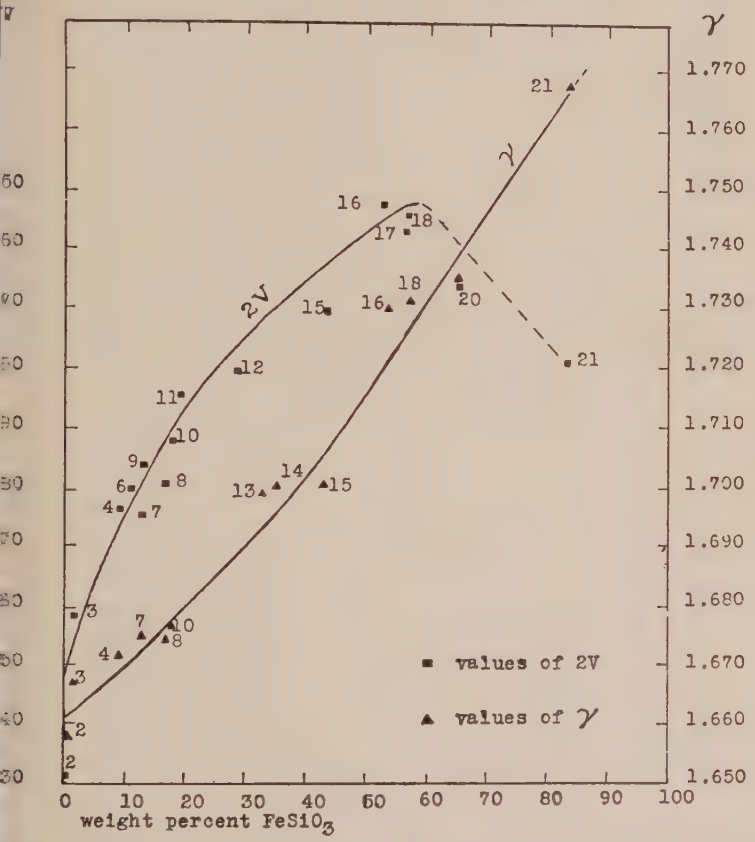
(*d*) Hypersthene from contaminated rock of Insch mass, one-sixth of a mile south of Easter Saphock, Old Meldrum, Aberdeenshire.

The hypersthene of specimen (*c*) is from the norite enclosing the xenoliths. It occurs as larger subhedra, about 0·5 mm. diameter, showing prismatic cleavages and schiller plates. The mineral is associated with biotite and magnetite in a base of plagioclase (about $Ab_{44}An_{66}$).

Specimen (*d*) is from a norite of the Insch mass;[1] contaminated by the absorption of argillaceous material. It forms short prisms and is accompanied by brown biotite, much red garnet, plagioclase ($Ab_{35}An_{65}$), and quartz.

[1] H. H. Read, Mem. Geol. Surv. Scotland, Explanation of Sheets 86 & 96, 1923, p. 135; and Geol. Mag., 1921, vol. 58, pp. 177–183.

In separating the mineral for analysis, the rock was crushed in a mond mortar with frequent sieving, until microscopic examination the powder showed the absence of compound grains. The bulk of



IG. 1. Variation of the optic axial angle (2V) and the refractive index (γ) h $FeSiO_3$ content in the orthorhombic pyroxenes. The numbers refer to le II.

felspar and quartz was removed by a preliminary separation in moform. The heavy crop, containing the hypersthene with some gnetite, garnet, hornblende, apatite, and zircon, was suspended in rici's solution (sp. gr. about 4·0). By careful addition of small antities of distilled water, the density of the liquid was so lowered t successive crops of minerals sank and were removed. Those ps consisting principally of hypersthene were repeatedly subjected

to this process, until examination under the microscope revealed them to be uncontaminated. The hypersthene was washed with distilled water until free from all trace of thallium. Quantities varying from $2\frac{3}{4}$ to nearly 4 grams were available for chemical analysis.

The refractive indices were determined by the immersion method in sodium-light at room-temperature, using mixtures of α-bromonaphthalene and methylene iodide. An Abbe refractometer with hemisphere n 1·7497 was used to measure the refractive index of the mixture. At least five determinations were made on each specimen.

In measuring 2V a Leitz universal-stage with segments n 1·649 was employed. The direct method of observing the emergence of an optic axis was followed with all the precautions against error detailed in the textbooks.[1] The values quoted in table I are the mean of at least six determinations in each case.

Table II below sets out the optic data of the enstatite-hypersthene

TABLE II. *Collected data for enstatite-hypersthene series.*

No.	Locality.	(Fe, Mn) SiO_3 %.	Opt. sign.	2V.	α.	β.	γ.	Sp.gr.
1.	Synthetic 'enstatite' ...	0	+	44–70°	1·640	1·646	1·652	3·174–3·876
2.	Bishopville, South Carolina (meteorite)	0	+	31	1·650	1·653	1·658	—
3.	Blithfield, Ontario (meteorite)	1·8	+	58	1·657	1·660	1·667	—
4.	Almeklovdal, Norway ...	9·4	+	76	1·660	1·665	1·671	3·274
5.	Diamond washings, S. Africa	9·2	+	74	—	1·669	1·675	3·20
6.	Fiskernäss, Greenland ...	10·8	+	79	—	1·650	—	3·21
7.	Espedalen, Norway ...	12·4	+	*c.* 75	1·666	1·670	1·675	3·254
8.	Loderio, Tessin, Switzerland	16·4	+	*c.* 80	1·662	1·667	1·674	3·232
9.	Kapfenstein, Styria ...	12·7	+	83	—	1·67	—	3·436
10.	Stora Ålke, Västerbotten, Sweden	17·9	+	*c.* 87	1·665	1·670	1·676	3·301
11.	Lauterbach, Hesse ...	19·2	−	85	—	1·685	—	3·34
12.	Farsund, Norway	28·8	−	81	—	1·695	—	3·351
13.	Franklin, North Carolina ...	33·3	−	—	1·685	1·696	1·699	—
14.	Nain, Labrador	34·2	−	—	1·690	—	1·700	3·415
15.	Arnage, Aberdeenshire (*a*)	43·7	−	71	—	—	1·703	3·49
16.	Quilquox, Aberdeenshire (*b*)	52·8	−	53	—	—	1·730	3·53
17.	Mt. Pelée, Martinique ...	56·7	−	58	—	—	—	3·54
18.	Quilquox, Aberdeenshire (*c*)	57·2	−	55	—	—	1·731	3·56
19.	Warrambu, W. Australia ...	66·5	−	—	1·654	1·664	1·678	3·45
20.	Easter Saphock, Aberdeenshire (*d*)	65·7	−	67	—	—	1·735	3·58
21.	Tunaberg, Sweden ...	83·5	−	80	1·750	1·760	1·768	3·85

[1] e.g. M. Berek, Universaldrehtischmethoden. Berlin, 1924, pp. 31–36, 50–64.

1. E. T. Allen, F. E. Wright, and J. K. Clement, Amer. Journ. Sci., 1906, ser. 4, vol. 22, p. 385. The synthetic material here described as enstatite has been shown not to yield the X-ray powder pattern of that material (N. L. Bowen and J. F. Schairer, Amer. Journ. Sci., 1935, ser. 5, vol. 29, p. 165).
2. E. T. Allen, F. E. Wright, and J. K. Clement, loc. cit., p. 385. The optic axial angle determined by Becke's method. The mineral contained inclusions of metallic iron.
3. R. A. A. Johnston and M. F. Connor, Trans. Roy. Soc. Canada, 1922, vol. 16, sect. 4, p. 187. The limits of the optical determinations are rather wide.
4. K. Johannson, Zeits. Kryst. Min., 1894, vol. 23, p. 152. The analysed material contained some amphibole.
5. H. L. Bowman, Min. Mag., 1900, vol. 12, p. 349. Clear grains from the diamond washings, probably from the Kimberley district. The analysis sums high.
6. J. Lorenzen, Medd. om Grønland, 1893, vol. 7, p. 24. Material analysed and described by this writer as 'kupfferite' was optically investigated by N. V. Ussing (Zeits. Kryst. Min., 1889, vol. 15, p. 615) and shown to be enstatite. The analysed material contained clinopyroxene.
7. H. S. Washington and H. E. Merwin, Amer. Min., 1923, vol. 8, p. 63 [M.A. 2–305]. The optic axial angle is given as approximate, the probable error not being stated.
8. F. de Quervain, Schweiz. Min. Petr. Mitt., 1934, vol. 14, p. 447 [M.A. 6–119]. Two analyses are given; the second, on pure material, does not show Al_2O_3, Fe_2O_3, CaO, or H_2O. The optic axial angle is approximate.
9. J. Schiller, Tsch. Min. Petr. Mitt., 1905, vol. 24, p. 307. The optic axial angle was measured in Schneider's rotation apparatus, assuming β of the mineral to be 1·67.
10. E. Grip, Bull. Geol. Inst. Univ. Upsala, 1932, vol. 23, p. 171 [M.A. 5–137]. The enstatite, which is often altered, occurs in serpentine lenses in a zoisite-amphibolite. Fresh material was used for the analysis.
11. A. Des Cloizeaux, Manuel de Minéralogie, Paris, 1874, vol. 2, pt. 1, p. xvi. The optic data are for red light.
12. A. Des Cloizeaux, Mém. Acad. Sci. Paris, 1867, vol. 18, p. 576. The optic data are for red light. The high (9·11) percentage of alumina shown in the analysis is remarkable.
13. E. P. Henderson, Amer. Min., 1931, vol. 16, p. 563 [M.A. 5–76]. No optic axial angle is given. The material contained small inclusions of biotite.
14. H. S. Washington and H. E. Merwin, loc. cit., 1923, p. 63. The analysed mineral contained intergrowths of augite, estimated at 5–10 % volume.
15. See (*a*) table I above.
16. See (*b*) table I above.
17. A. Lacroix, La Montagne Pelée et ses éruptions, Paris, 1904, p. 506. The hypersthene was separated by heavy liquids and hydrofluoric acid from an andesite.
18. See (*c*) table I above.
19. E. S. Simpson, Journ. Roy. Soc. W. Australia, 1930, vol. 16, p. 25 [M.A. 4–346]. The large cleavage pieces of hypersthene contained about 10 % of impurities, chiefly magnetite, not removed before analysis.

20. See (*d*) table I above.
21. N. Sundius, Årsb. Sveriges Geol. Undersök., 1932, vol. 26, p. 1 [M.A. 6–118]. The high iron content and refractive indices with large optic axial angle are noteworthy.

series collected from the literature, as having been determined upon analysed specimens. In collecting the optical data, only 2V and γ have been considered, and any publication not giving at least one of these quantities has been ignored. The petrographer who desires to know the approximate composition of an enstatite or hypersthene can determine the index γ rapidly by the immersion method, while a search for fragments yielding the other principal indices would take much time.

In addition to the foregoing there are several analyses extant which have been made on material reported from the same locality as that on which optical determinations have been made. As some of these have been used in constructing diagrams of variation, it is necessary to consider them, although none have been employed in fig. 1. They are set out in table III, and some notes on them are offered below.

Table III. *Uncertain data for enstatite-hypersthene series.*

No.	Locality.	(Fe,Mn) SiO_3 %.	Opt. sign.	Optic axial angle.	α.	β.	γ.
22.	Zdjar Berg, Moravia ...	5·6	+	(*a*) 2V 69°		1·639	—
				(*b*)	1·656	1·659	1·665
23.	Kupferberg, Bavaria ...	13·3	+	2V 82	—	1·668	—
24.	Balsfjord, Norway	15·0	+	2H 112	—	—	—
25.	Kraubat, Styria	18·6	—	2H 106			
26.	Labrador	31·9	—	(*a*) 2V 50	1·692	1·702	1·705
				(*b*) 2V 72	—	1·69	—
27.	St. Paul's Island, Labrador	41·0	—		1·715	—	1·727
28.	Aranyer Berg, Hungary ...	23·9	—	2H 84	—	—	—
29.	Krakatoa	56·7	—	2H 79	—	—	—
30.	Mt. Dore, France	56·0	—	(*a*) 2E 101			
				(*b*) 2H 59			
				(*c*) 2V 62 ± 5	1·696	1·709	1·712
				(*d*) ...	1·704–1·707		1·720–1·723

22. A. Kenngott, Sitzungsber. Akad. Wiss. Wien, 1855, vol. 16, p. 162, gave a chemical analysis but no optical data when he established the new species enstatite on material from this locality. Des Cloizeaux (Man. Min., 1862, vol. 1, p. 540) determined 2V and $\beta(a)$, while C. Hintze (Handbuch Min., 1897, vol. 2, p. 964) quotes the indices obtained by Mallard (*b*)

3. C. W. Gümbel, Geogn. Beschr. Bayern, 1879, vol. 3, p. 157, published an analysis by von Ammon of material occurring in serpentine. Optical data for red light are by Des Cloizeaux (Mém. Acad. Sci. Paris, 1867, vol. 18, p. 555).

4. H. Rosenbusch, Neues Jahrb. Min., 1884, vol. 1, p. 195. 2H is given for yellow light. An analysis was made on 0·82 g. of somewhat impure material.

5. H. Rosenbusch, Mikr. Phys., 1905, vol. 1, pt. 2, p. 147, associated G. Tschermak's determination of 2H with an analysis by Regnault, Ann. Mines, 1838, vol. 14, pt. 3, p. 147. Another analysis is by H. Höfer, Jahrb. Geol. Reichsanstalt, Wien, 1866, vol. 16, p. 445.

6. M. Lévy and A. Lacroix, Minéraux des roches, 1888, p. 261, publish optic data for a hypersthene from Labrador (*a*). In A. N. Winchell, loc. cit., p. 507, fig. 1, no. 15, the index β of this determination is used with a 2V differing from Lévy and Lacroix's value, and is coupled with A. Remele's analysis of hypersthene from St. Paul's Island (Ber. Deutsch. Chem. Gesell., 1868, vol. 1, p. 143).

7. J. E. Wolff, in Rosenbusch, Mikr. Phys., 1905, vol. 1, pt. 2, p. 147, gives values for α and γ for hypersthene from St. Paul's Island, Labrador. A. N. Winchell, loc. cit., fig. 1, no. 17, uses a value (1·723) for γ ascribed to J. E. Wolff, and 2V obtained by Des Cloizeaux on material from Labrador (26*b*) (Mém. Acad. Sci. Paris, 1867, vol. 18, p. 573). These are joined with the analysis by A. Damour (Ann. Mines, 1844, vol. 4, p. 157).

8. A. Koch, Zeits. Kryst. Min., 1879, vol. 3, p. 307, gave an analysis of a new mineral ' szaboite ', which showed a high content of Fe_2O_3. J. A. Krenner, Zeits. Kryst. Min., 1884, vol. 9, p. 255, considered the analysis to be in error, and gave a value for 2H. F. Koch, Zeits. Kryst. Min., 1885, vol. 10, p. 99, published a new analysis, showing the presence of FeO, MgO, and CaO, and suggested the identity of the mineral with hypersthene. The iron silicate content given here is calculated from F. Koch's analysis.

9. J. A. Krenner, Zeits. Kryst. Min., 1885, vol. 10, p. 101. This determination of 2H and the analysis (J. W. Retgers, Zeits. Kryst. Min., 1886, vol. 11, p. 418) were made on material isolated from volcanic dust falling in different localities.

10. A. Des Cloizeaux, Man. Min., 1874, vol. 2, pt. 1, p. xviii, gives values of 2E for three wave-lengths (*a*). J. A. Krenner, Zeits. Kryst. Min., 1884, vol. 9, p. 262, gives 2H (*b*). Recent determinations by B. E. Warren and D. I. Modell, Zeits. Krist., 1930, vol. 75, p. 1 (*c*), and by N. L. Bowen and J. F. Schairer, Amer. Journ. Sci., 1935, ser. 5, vol. 29, p. 151 (*d*), give different values. The only analysis is an old one by Laurent showing 5·2% MnO.

A consideration of the above notes shows that much of the data which we possess is not of the first quality. In six out of the twenty undoubted orthorhombic pyroxenes of table II impurities were present in the material analysed. In five cases γ and in three cases 2V were not determined, while in a further four 2V is doubtful. Several analyses do not show Fe_2O_3, MnO, or CaO, although it is probable

that these oxides occur to some extent in all natural enstatites and hypersthenes.

In constructing the diagram (fig. 1) it was found that more regularity was obtained when all the iron in the analyses was calculated as FeO, and MnO, if present, added. $MgSiO_3$ and $CaSiO_3$ were calculated separately and combined. Alumina, titania, alkalis, &c., were neglected; it is certain that their influence on the optical properties is small.

From the figure it is seen that three considerable ranges of iron silicate content are unrepresented by optical measurements, i.e. between about 20–30, 34–44, and 65–84 % $FeSiO_3$. While determinations in the lower parts would give more precision to the curves, yet additional data for iron-rich hypersthenes would be of the greatest interest. In the case of the curve of 2V, it is probable that a minimum is reached at about 55–60 % $FeSiO_3$, after which 2V tends once more toward 90°, although until more data becomes available it is not possible to draw any definite line.

In view of the imperfect state of the data it is clear that no high degree of accuracy can be claimed for these curves. It seems probable that, until synthetic material suitable for accurate optical investigation can be prepared, considerable uncertainty will attach to our knowledge of the variation of the series.

In conclusion, I wish to thank Professor H. H. Read, who suggested this study, Dr. A. W. Groves who made the chemical analyses, and the Government Grant Committee of the Royal Society for a grant defraying the cost of the analyses.

Anomalies in the analytical determination of water in epidote.

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NUMEROUS veins and veinlets of epidosite traverse the crystalline schists and associated igneous rocks of the Malvern complex. ıey are fine-grained, compact rocks, of uniform texture and pale ·enish-yellow colour, and vary in composition from almost pure ıdote to mixtures of epidote with small quantities of quartz, ıene, sericitic mica, apatite, and, in almost insignificant amount, ›ite.

Analytical investigation of these rocks revealed the fact that the idote they contain holds its water more tenaciously than has herto been suspected : the determination of water-content by the thods usually applied to the analysis of rocks and minerals gave sults which were so seriously low as to suggest that the mineral as essentially anhydrous. Though more drastic methods increased e yield considerably, they failed to liberate more than about 75 % the amount of water which, theoretically, should be present.

The anomaly was first observed in an analysis (made by the thor) of almost pure epidote-rock (specimen A) taken from a vein the lower level of the most westerly quarry at the north end of the alvern Hills—one of the Pyx quarries. The figure obtained for e sum of all the constituents of the rock was only 98·46 % ; the tal water-content was only 0·06 %, one-third of which was given) at temperatures below 110° C. The determination of water was rried out by the ordinary method, viz., by the use of an absorption pparatus, in contact with which the sample, placed in a silica boat, as heated in a silica tube in a furnace for one hour, the temperature sing to approximately 1000° C., and a current of dry air passed rough the tube.

To check this disturbing result, the determination of water was

repeated three times; but the four sets of figures, as shown below, were essentially the same:

Total water-content . . .	0·06; 0·05; 0·05; 0·06 %.
Combined water (above 110° C.) .	0·04; 0·03; 0·03; 0·04 %.
Theoretical percentage . . .	1·80–2·00.

In the last two determinations, heating was continued for about 2½ hours, instead of the customary 1 hour; and the furnace was heated as intensely as possible.

A sample of another epidosite (specimen B, from the eastern Pyx quarry in the same hill) was then analysed by Dr. A. W. Groves, who also obtained a low total for the rock (98·52 %), and a low figure for the total water-content (0·35 %, being 0·28 % combined water and 0·07 % free water).

Dr. Groves next repeated the water determination on specimen A, and succeeded in raising the figure for total water-content to 0·15 % (0·12 % combined water, 0·03 % free water). He also analysed a duplicate of this specimen A, obtaining 0·14 % total water-content, only half of which was in the combined state; while on analysing a less pure epidosite from a vein in contact with granite on the eastern slope of the same hill he returned a figure of 0·56 % combined water and 0·10 % free water.

The persistence of this anomaly raised the question whether the mineral under consideration was a true epidote, or some other species having essentially the same physical and optical properties, in which the water had been replaced by some other constituent of rare occurrence. To decide this question, Dr. R. W. B. Pearse, of the Physics Department, Imperial College of Science and Technology, kindly carried out a spectroscopic investigation of specimen A, with a view to discovering whether any unusual element was present which might have passed through the analysis undetected; but he failed to identify any such element, or to discover any substance not already determined in the course of the chemical analysis. Mr. F. A. Bannister, of the Mineral Department, British Museum, then very kindly took X-ray powder photographs of the epidosite A and the pure mineral (specimen C), which the author had separated from specimen A by elutriation, fractional gravity separation in Clerici solution, and electro-magnetic methods; on comparing these with similar photographs of pure epidote from a well-known locality, it was seen that the two sets of photographs were so exactly similar as to prove that the mineral C was a true epidote.

Since tests showed that sulphur or chlorine, released only by sion, were not present in greater amount than would be accurately licated by the figures obtained by acid attack, and that carbon s absent, while fluorine had already been determined and was not sent in such quantities as to suggest that it had replaced water, became clear that the shortage in the totals for specimens A and B uld only be accounted for by incomplete expulsion of the water.

Fusion methods were then employed for the determination of the ter in specimens A, B, and C, a platinum boat and combustion-ass tube being used. First the powdered epidosite was mixed with dium carbonate: this failed to give a complete melt at 800° C., d 'fritting' produced no higher figure for water, as the rock was attacked. Carefully dried sodium tungstate was then used instead, d the full temperature of 1000° C. was maintained for a prolonged riod. A much higher figure was thus obtained, but the decompo-ion was not complete in any one case, and the largest figure for ter was reached where decomposition had proceeded farthest. The ures for water obtained by the sodium tungstate fusion method, as mpared with those resulting from the normal method, were as llows:

	Specimen A.	B.	C (pure mineral).
ater expelled below 110° C.	0·03	0·07	0·03 %
,, ,, above 110° C.	0·12	0·28	0·12
,, ,, on heating with sodium tungstate	1·15	0·41	1·17
otal water	1·30	0·76	1·32

In the case of specimen B, heating with sodium tungstate was less olonged than in the other two cases; whereas the residue of ecimen C from the first fusion with sodium tungstate was recovered, ashed, dried at red-heat, and then subjected to a second fusion with dium tungstate. A figure of 0·73 % was obtained from the first sion, and a further 0·44 % of water was expelled on re-fusing; but e indications were that the mineral still retained some water ·2 %–0·3 %) which was even now unexpelled.

Finally, in view of the almost complete absence of CO_2, and the tremely low percentage of FeO in the pure mineral, it seemed ssible that the determination of loss on ignition would give a good proximation to the correct figure for total water. A temperature 1300–1400° C. was employed, and the mineral blasted for half an

hour; the loss was equivalent to 2·52 %, but the mineral had sintered and fused on the bottom of the crucible, so that evidently some of it had volatilized at this temperature.

The complete analyses of the three specimens A, B, and C are given below:

	Specimen A (A. F. Smethurst).	Specimen B (A. W. Groves).	Specimen C (pure mineral) (A. W. Groves).
SiO_2	42·94	52·27	37·22
TiO_2	0·41	0·91	0·33
Al_2O_3	20·00	15·34	21·99
Fe_2O_3	12·81	10·13	14·25
FeO	0·30	0·92	0·63
MnO	0·18	0·17	0·17
MgO	0·16	0·37	0·28
CaO	20·60	17·07	23·22
Na_2O	0·27	0·07	nil
K_2O	0·36	0·21	0·09
H_2O (Na_2WO_4)	1·15	0·41	1·17
H_2O (>110° C.)	0·12	0·28	0·12
H_2O (<110° C.)	0·03	0·07	0·03
P_2O_5	0·13	0·37	0·11
BaO	nil	0·10	nil
SrO	0·04	0·11	0·17
CO_2	0·05	0·15	nil
F	0·03	0·08	0·03
Cl	0·03	0·04	0·08
SO_3	nil	n.d.	n.d.
S	0·07	n.d.	n.d.
V_2O_3	n.d.	n.d.	0·05
Li_2O	n.d.	nil	nil
CuO	0·01	n.d.	n.d.
Cr_2O_3	0·002	n.d.	0·002
	99·69	99·07	99·94
O for F & Cl	0·02	0·04	0·03
	99·67	99·03	99·91

The molecular proportions for the pure mineral C calculated from the above figures are as follows:

	Molec. Propns.	No. of (O, OH, F) atoms.	No. of metal atoms on basis of 26 O atoms.
SiO_2	0·620	1·240	6·03
TiO_2	0·004	0·008	0·04
Al_2O_3	0·216	0·648	4·20
Fe_2O_3	0·090	0·270	1·75
FeO	0·009	0·009	0·09
MnO	0·003	0·003	0·03
MgO	0·007	0·007	0·07
CaO	0·415	0·415	4·03
K_2O	0·001	0·001	0·02
H_2O	0·073	0·073	1·42
F_2	negligible	—	—
		2·674	

Except in the deficiency of water, analysis C of the pure mineral rresponds closely with the empirical formula usually adopted for idote, viz., $HCa_2Al_3Si_3O_{13}$ or $H_2O.4CaO.3Al_2O_3.6SiO_2$. On the sis of 26 oxygen atoms the analysis gives:

$$H_{1\cdot42}Ca_{4\cdot03}(Al,Fe)_{5\cdot95}Si_{6\cdot03}O_{26}$$

from the molecular proportions with $6SiO_2$:

$$0\cdot71H_2O.4\cdot01CaO.2\cdot96(Al,Fe)_2O_3.6SiO_2.$$

In either case, the figures suggest that the mineral C has the exact nposition of a normal epidote, except that there is a striking ficiency of over 25 % in the water, i.e., in the hydrogen-content to ich it is an index.

But the following unusual chemical behaviour was noticed when chemical analysis was being carried out:

1. The mineral underwent no colour change after being heated to 00° C., and the residue could not be decomposed with concentrated l, even after repeated evaporations on the water-bath.

2. The mineral was not attacked by concentrated HCl, either fore or after ignition.

3. The mineral was extraordinarily resistant to the attack of fused dium carbonate.

It seemed possible that the anomaly in regard to tenacity of water d the above abnormalities in chemical reaction were both indicative some unusual feature in the internal structure of the mineral.

To ascertain whether they were peculiar to this individual speci- en of epidote, or common to all occurrences of the mineral, periments were carried out on three typical examples of epidote ast generously supplied from the mineral collection of the British useum. The chemical behaviour was identical in every case with at observed in the Malvern epidote (specimen C), and the same ficulty was found in driving off the water, as will be seen from the llowing figures:

	I.	II.	III.
O expelled below 110° C.	0·14	0·08	0·01 %
O ,, ,, 1000° C.	0·29	0·37	0·24
O ,, on heating with sod. tungstate ...	1·25	1·01	1·00
tal water	1·68	1·46	1·25

. Balmedie quarry, five miles north of Aberdeen.
. (Clinozoisite), Moneta mine, Timmins district, Ontario.
. Kammegg, Steinhaushorn, Haslithal, Canton Bern, Switzerland.

A detailed scrutiny of all the recorded analyses of epidote shows at there are a considerable number of instances in which the figure

for water is low. E. Ludwig (1872) quotes 89 analyses, in which the percentage of water ranges from 1·78 % to 2·46 %, but in only one case is it abnormally low, viz., 0·63 %. W. Eitel (1919) cites 120 analyses of common epidote, of which 32 contain figures below 1·60 % for the water-content: but many of these also are old analyses, in which the loss on ignition was taken as the percentage of water present, a method which, as Eitel remarks, 'leaves very much to be desired'. C. Doelter, in his 'Handbuch der Mineralchemie' (1915) gives over 100 analyses of epidote, and in 10 of these the water-content is low. A search, by the present author, of the literature on epidote has revealed 16 analyses published since the year 1900 in which the percentage of water is less than 1·30 %, and in some cases it falls as low as 0·10–0·30 %. In 6 of the 16 analyses the total for the sum of all the constituents is low by something like 0·5 %, which suggests that in these cases, as in the case of the Malvern epidote, it was impossible to drive off all the water by the methods usually available.

There appears to be no relation between low water-content and the amount of any other constituent present; it does not vary, for example, with the ratio of Fe_2O_3 to Al_2O_3. The anomalous behaviour of water is evidently not found in all epidotes; but clearly it does exist in some cases.

Now in all ordinary circumstances the water of a rock or mineral present in the 'combined' as well as in the 'free' state, is completely and easily driven off when the sample under investigation is heated alone for one hour in a silica tube at a temperature of 1000° C. It is very unusual to find any difficulty in obtaining correct figures for water by this method; but W. F. Hillebrand (Bull. U. S. Geol. Surv., 1919, no. 700, p. 78) states that certain minerals, such as talc, topaz, chondrodite, and staurolite, do not give up their water wholly, even over the blast. H. S. Washington mentions the same four minerals as being particularly tenacious of their water. Dr H. F. Harwood informs me that he personally has only known this method to fail in the case of talc; and Mr. E. G. Radley tells me that he has only known one mineral in addition to those given above which offers special difficulty, namely phlogopite, and even this yields up its water by the silica tube method, if the heating is prolonged for about three hours. It would thus appear that certain types of common epidote must be included in the list of the very few minerals which are extremely retentive of their water. This in itself

s an interesting fact; but its interpretation raises points which may urn out to be of deep significance.

W. F. Hillebrand (loc. cit., p. 65) attempts a classification of the arious combinations of hydrogen found in minerals, in accordance ith the difficulty of expelling their hydrogen atoms in the form of ater. In this scheme he notes that it is most difficult to drive off he water in cases where what he calls the 'acidic' linkage (H) is resent, whereas when the 'basic' group (OH) occurs the expulsion f water is much easier. In accordance with this principle, it would ppear probable that in those cases where the water of epidote is ery firmly held, the hydrogen is present in the 'acidic' rather than he 'basic' state.

Various modifications of the empirical formula of epidote given bove have been suggested [1] in which an (OH) group is included, e.g., $SiO_4)_3Al_2(AlOH)Ca$. But recent X-ray work has revealed the xistence of an (OHO) group; and where such a group is present, here is a marked increase in stability. It is conceivable that some uch structure as this might occur in certain forms of epidote, and ight result in the observed anomaly, viz., the extreme stability of heir hydrogen atoms as manifested by their marked tenacity of ater. However, until the structure of epidote has been fully orked out by modern X-ray methods, the problem cannot be olved: it is hoped that the pointing out of this curious feature of he mineral may induce some physicist to undertake the task.[2]

In conclusion the author wishes to thank Dr. A. W. Groves for arrying out two complete analyses and several water determinations, or much helpful discussion of the problem, and for the interest he as displayed in the chemical aspect of the matter; Mr. F. A. annister for most generously taking X-ray photographs of the ineral, and for valuable suggestions and advice; Dr. R. W. B. earse for carrying out a spectroscopic investigation; Dr. L. J. Spencer or supplying the specimens of normal epidote; Dr. H. F. Harwood nd Mr. E. G. Radley for information with regard to their own xperiences in the analysis of epidote; and above all to Dr. A. rammall for constant help and advice.

[1] P. Groth, Tab. Übers. Min., 1889, p. 109; B. Gossner and F. Mussgnug, Centr. lin., Abt. A, 1930, p. 369 [M.A. 5–324]; D. J. Bujor, Zeits. Krist., 1931, vol. 78, . 386 [M.A. 5–29].

[2] I am informed by Prof. W. L. Bragg that work is already being carried out n the subject in his laboratory.

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MINERALOGICAL ABSTRACTS

(Vol. 6, No. 3, September, 1935.)

Notices of Books.

TRÖGER (W. Ehrenreich). *Spezielle Petrographie der Eruptivgesteine. Ein Nomenklatur-Kompendium.* Berlin (Deutsch. Min. Gesell.), 1935, vii + 360 pp., 1 fig. Price 14 Mk. (bound 16 Mk.).

This book, published by the German Mineralogical Society, is a valuable and handy book of reference. 777 species of igneous rocks are grouped in 32 families ranging from perazidites (the most acid) to ilicotelites (the most basic). Under each species useful information is concisely given in systematic order: name of author (but without initials), date and bibliographical reference, original locality, a brief definition, a full chemical analysis with 'Niggli values' and 'C I P W' symbol, quantitative mineralogical composition, colour ratio, and any synonyms or varieties. A statement of specific gravity is lacking. The quantitative mineralogical compositions have in most cases been deduced by the author himself from micrometric measurements made on a large number of micro-sections borrowed from various sources—a laborious and useful piece of work. Next follows an alphabetical list of synonyms and group names under nos. 778–1022, giving author, date, and brief description. Many rock names are derived from the original locality, and in other cases it would have been useful to give the derivation. The book ends with some useful tables and an alphabetical index of all (1670) names of igneous rocks. An index of authors would also have been useful, but, as pointed out in the introduction, five petrographers (A. Lacroix, H. Rosenbusch, W. C. Brögger, A. Johannsen, and H. S. Washington) are together responsible for no less than 303 names. L. J. S.

BROOK (Welton Joseph). *Metallurgical spectrum analysis.* Stanford University, California (Stanford Univ. Press) & London (Humphrey Milford, Oxford Univ. Press), 1935, vii + 82 pp. (4to), 9 pls., 3 text-figs., 24 pls. (35 × 23 cm.) in portfolio. Price 56*s*.

A description of the construction and operation of a concave grating spectrograph (2·64 mm. = 1 Å. in the ultra-violet) specially designed

for the quantitative and qualitative examination of samples of metals and alloys. The author recommends the use of the Pfund type iron arc, and gives a series of twenty plates for visual comparison with spectrograms which need to be enlarged. The complete spectra of thirty-one metals are plotted vertically above a portion of the iron spectrum reproduced at the bottom of each plate. A chart is also given of the iron spectrum alone. In addition, fairly complete data compiled from the International Critical Tables, vol. 5, are tabulated for thirty-eight elements, and more or less complete data for a further twenty-six elements. Two spectral regions are covered by these tables, 2800 to 3400 Å. and 5000 to 5600 Å. These will be found invaluable to all spectrographers. The visual spectrum atlas, however, is necessarily confined to those workers possessing instruments of the grating type and of about the same dispersion. F. A. B.

Branson (E. B.) & Tarr (W. A.). *Introduction to geology.* New York and London (McGraw-Hill Book Company), 1935, viii + 470 pp., 456 figs. Price 21*s*.

This book results from the experience gained during over twenty years of teaching by the professors of geology and palaeontology and of geology and mineralogy in the University of Missouri. The authors acknowledge their greatest debt to their students, who have shown the way to improvement. There are surely quite a sufficient number of elementary text-books on geology, and it is not incumbent on every professor of geology to produce still another. A striving for simplicity in the present volume leads to some statements which, in being only partly accurate, may give rise to misunderstanding. There is a wealth of original illustrations, some of which are rather crude.

L. J. S.

Walther (Johannes). *Einführung in die deutsche Bodenkunde.* Verständliche Wissenschaft, vol. 26, Berlin (Julius Springer), 1935, viii + 172 pp., 30 figs. Price 4·80 Mk.

The title of this neat and well-printed little book is rather misleading. It does not deal with German soils from an agricultural point of view (Bodenkunde). But rather it is a popular account of surface geology and physical geography (Erdkunde) giving German examples. Different types of soils are mentioned, but so also are economic minerals (Bodenschätze). L. J. S.

Meteorites and Tektites.

Recent research literature on meteorites received. Popular Astronomy, Northfield, Minnesota, 1934, vol. 42, p. 106.

Recent research literature on meteorites—second 1934 list. Ibid., pp. 226–227.

Leonard (Frederick C.) & Webb (Robert W.). *Bibliography of meteoritics. Third 1934 list.* Ibid., pp. 342–344.

—— —— *Bibliography of meteoritics. Fourth 1934 list.* Ibid., pp. 600–602.

—— —— *Bibliography of meteoritics: first 1935 list.* Ibid., 1935, vol. 43, pp. 251–253.

Titles of papers, including also anonymous notes and reviews.

L. J. S.

Manian (Samuel H.), Urey (Harold C.), & Bleakney (Walker). *An investigation of the relative abundance of oxygen isotopes O^{16} : O^{18} in stone meteorites.* Journ. Amer. Chem. Soc., 1934, vol. 56, pp. 2601–2609, 2 figs.

The meteoric stones (Mocs, Homestead, and Knyahinya) examined are those which had been recorded with high helicentric velocities, and therefore thought to have come from interstellar space. The ratio $O^{16} : O^{18}$ was found to be 514 : 1, the same (within the limits of experimental error ± 13) as for terrestrial granite and $KClO_3$.

L. J. S.

Lewis (Gilbert N.). *The genesis of the elements.* Physical Review, 1934, ser. 2, vol. 46, pp. 897–901, 2 figs.

It is suggested that a great part of the matter in the universe consists of the two stable isotopes of iron and the two stable isotopes of nickel, which should not be liable to spontaneous transmutations. The earth's crust and the silicate portion of stony meteorites are supposed to arise by decomposition of these atoms by cosmic radiation. The relative abundance of the principal elements of stony meteorites is accounted for. M. H. H.

Wainwright (G. A.). *Some aspects of Amūn.* Journ. Egyptian Archaeology, London, 1934, vol. 20, pp. 139–153, 9 figs.

—— *Amūn's meteorite & omphaloi.* Zeits. Ägypt. Sprache u. Altertumskunde, Leipzig, 1935, vol. 71, pp. 41–44, 6 figs.

Amūn's sacred object at Thebes was probably a meteorite, its shape being compared with a portion of a pear-shaped siderite. Those at

Siwah and Napata were dome-shaped omphaloi fashioned from terrestrial stones. [Cf. M.A. **6**–10.] L. J. S.

Wylie (C. C.). *The annual deposit of meteoric material.* Popular Astronomy, Northfield, Minnesota, 1935, vol. 43, pp. 120–121, 1 fig.

The estimated number of meteors visible to the unaided eye is 24,000,000 per day, while telescopic meteors must number millions of millions. Of detonating meteors about 10 per year are seen within a circle of 280 miles radius. The weight of material added per year is estimated at 2×10^6 kg., sufficient to increase the radius of the earth by one inch in 2×10^{10} years. [Cf. M.A. **5**–402.] L. J. S.

Nininger (H. H.). *The surface features of meteorites.* Popular Astronomy, Northfield, Minnesota, 1935, vol. 43, pp. 121–126.

The irregular form of meteoric stones is due to the breaking up of a larger mass in the earth's atmosphere, and the subsequent rounding of the edges of the several fragments, which fall as a shower.

L. J. S.

Jander (Wilhelm) & Senf (Hans). *Das Gleichgewicht* $FeO + Ni \rightleftarrows NiO + Fe$ *im Schmelzfluß.* Zeits. Anorg. Chem., 1933, vol. 210, pp. 316–324, 2 figs.

—— —— *Die Abhängigkeit des Gleichgewichts* $FeO + Ni \rightleftarrows NiO + Fe$ *im Schmelzfluß von* SiO_2*-Zusatz. (III. Mitteilung über Gleichgewichte zwischen Metallen, Sulfiden und Silikaten im Schmelzfluß.)* Ibid., 1934, vol. 217, pp. 48–52, 2 figs.

Jander (Wilhelm), Zweyer (Hans), & Senf (Hans). *Das heterogene Gleichgewicht* $FeS + Ni$*-Silikat* $\rightleftarrows NiS + Fe$*-Silikat im Schmelzfluß. (IV. Mitteilung über Gleichgewichte zwischen Metallen, Sulfiden und Silikaten im Schmelzfluß.)* Ibid., 1934, vol. 217, pp. 417–426, 2 figs.

The equilibrium $FeO + Ni \rightleftharpoons NiO + Fe$ obeys the simple law of mass action; the equilibrium constant $K = [Fe]\,[NiO]/[FeO]\,[Ni]$ (the concentrations being expressed in mols. %) varies with temperature, and is well expressed by $\log K = 2{\cdot}208 - 7700/T$, T being the absolute temperature. At 1600° C. the % Ni in the oxide phase is very small until the % Ni in the metal phase exceeds 50–60 %. The constant decreases markedly with increase of silica up to about 12 % SiO_2 by weight in the silicate layer (i.e. the proportion of NiO in the silicate layer decreases). The temperature coefficient is also affected; with

> 12 % SiO_2 in the silicates, $\log K = 1{\cdot}29 - 6300/T$. The equilibrium FeS + Ni-silicate⇌NiS + Fe-silicate also obeys the simple mass action law, with

$\log K = \log [NiS][Fe\text{-silicate}]/[FeS][Ni\text{-silicate}] = -0{\cdot}75 - 2600/T$;

thus the Ni enters the sulphide phase in preference to the silicate to a very marked degree. The equilibrium is not appreciably influenced by the SiO_2 content of the silicates, at least so long as this exceeds 30 % SiO_2. Nor could any appreciable effect be found with additions of Na_2SiO_3, $CaSiO_3$, $MgSiO_3$, or CaF_2. Systems with less sulphur than corresponds to (Fe,Ni)S for the sulphide phase show no alteration of the equilibrium constant until the sulphide phase contains less than 12 % S, then a continuous trend to its value for the system Fe + Ni-silicate⇌Ni + Fe-silicate. Comparison with data obtained from slags and mattes from technical nickel smelters reveals some anomalies. The results are compared with those of H. zur Strassen [M.A. **5**–8, 153] and some discrepancies pointed out. M. H. H.

Franke (Walter), Meisel (Karl), & Juza (Robert). *Über die Verwandtschaft von Phosphor zu Eisen.* Zeits. Anorg. Chem., 1934, vol. 218, pp. 346–359, 3 figs.

Meisel (Karl). *Über die Kristallstruktur des FeP_2.* Ibid., pp. 360–364, 1 fig.

Fusion curves, densities, vapour-pressure curves, and X-ray data are given for the system Fe–P. The compounds found are FeP_2, FeP, Fe_2P, and Fe_3P (schreibersite). The crystal-structure of FeP_2 has been fully worked out; it belongs to the marcasite group.

M. H. H.

Lecompte (M.). *L'aérolithe du Hainaut.* Mém. Mus. Roy. Hist. Nat. Belgique, 1935, no. 66, 39 pp., 3 pls.

A stone fell between 8 and 9 p.m. on November 26, 1934, in the commune of Bettrechies, dep. Nord, France, only 60 metres east of the Belgian frontier [50° 19′ N., 3° 44′ E.], making a hole 60 cm. deep and 80 cm. in diameter. Only five fragments with a total weight of 922 grams were recovered: the whole mass perhaps weighed 15–20 kg. Sp. gr. 3·64–3·68. It is a brecciated intermediate chondrite, with lighter grey angular fragments in a dark blue-grey ground. Analysis by M. Ronchesne gave SiO_2 38·51, TiO_2 0·02, Al_2O_3 0·18, Fe_2O_3 1·04, FeO 16·50, NiO 0·20, CoO 0·02, MnO 0·12, MgO 22·57, CaO 2·07, Na_2O 0·52, K_2O 0·18, P_2O_5 0·03, Fe 14·64, Ni 0·71, Co 0·07, S 3·87 = 101·25, corresponding with olivine 34·54, hypersthene 33·98,

diopside 8·12, aegirine 2·77, orthoclase 0·55, nickel-iron 8·21, troilite 10·56 = 98·73. L. J. S.

Jaroš (Zdeněk). *Pád meteoritu v Sazovicích u Zlínu na Moravě.* [Meteorite fall at Sazovice near Zlín, Moravia.] Příroda, Brno, 1934, vol. 27, pp. 281–284, 5 figs.

A meteoric stone fell on June 28, 1934, at Sazovice in eastern Moravia, and was presented to the Country Museum at Brno. It weighs 411·98 grams and measures 8·8 × 7·2 × 5·1 cm. It shows fine surface markings and a black crust 0·3–0·4 mm. thick. It consists of olivine, enstatite, monoclinic pyroxene, and grains of metallic iron, and belongs to the group of veined grey chrondrites. F. S.

Khan (Mohd. A. R.). *The meteorite fall of 1928 near Purna.* Journ. Osmania Univ. Coll. Hyderabad, 1934, vol. 2, pp. —, 1 pl. (reprint 2 pp.).

A shower of stones was seen to fall at 5 p.m. on September 29, 1928, over an area of about 2½ square miles near Purna in Hyderabad. Two stones were recovered at Naoki, one at Malegaon, and several at Kawagaon. Figures are given of a stone of 10,320 grams from Kawagaon; it has sp. gr. 3·49, and consists of olivine and enstatite with grains of nickel-iron and troilite. [These have been previously described as the Naoki fall, M.A. **4**–421, Min. Mag. **23**–303.] L. J. S.

Khan (Mohd. A. R.). *Meteors and meteoric iron in India.* Secunderabad (privately printed by Moses & Co.), [1934], 20 pp., 1 pl.

A brief account of the main facts concerning meteors and meteorites, with special reference to meteoric iron in India, has been abridged from the author's presidential address to the Hyderabad Science Association on July 14, 1934. Extracts are given from old books of the fall of a meteorite (iron or stony-iron) weighing about 2 kg. which fell in 1621, during the reign of King Jahangir, in the Jalandhar district, Punjab, from which sword blades were made. None of the material is known to have been preserved, and the fall is not recorded in meteorite lists [Min. Mag. **23**–290; see H. Blockmann, Proc. Asiatic Soc. Bengal, 1869, no. 6, pp. 167–169, who gives the weight as 1967 grams, and the date of fall as April 10, 1621]. Extracts from newspaper accounts record the fall of a deeply pitted mass (about 23 lb.) of meteoric iron on July 23, 1934, near Hapur, Meerut district, United Provinces. L. J. S.

EHRMAN (Gunnar). *Über ein Nickeleisen aus Tannuola (Mongolei).* Acta Acad. Aboensis, Math. et Physica, 1923, vol. 3, no. 1, 12 pp., 2 pls.

In 1913 many large and small masses of iron were found in the old-washings on the Tschinga [Чинга, Chinga] stream, a tributary of the Upper Yenisei from the Tannu-ola Mts. in Mongolia. The material was described by Backlund and Khlopin in 1915, and was then believed to have been derived from the basic rocks of the district. V. G. Khlopin's analysis gave Fe 82·36, Ni 16·71, Co 0·40, Si 0·04, C nil, P traces, insol. 0·25 = 99·76. The iron, sp. gr. 7·868, is fine-grained and consists mainly of plessite with troilite, daubreelite, and schreibersite. A crystal of monoclinic habit of iron sulphide is believed to be distinct from troilite. The masses have a skin of magnetite and an outer heating zone, and they are probably meteoritic. They are referred to as the Tschinga iron. L. J. S.

LACROIX (Alfred). *Sur des météorites pierreuses tombées dans l'Aïr (Colonie du Niger).* Compt. Rend. Acad. Sci. Paris, 1935, vol. 200, pp. 1641–1643.

A stone (20 kg. of broken fragments) is reported to have fallen in 1925 some 70 km. WSW. of Iférouane [19° 5′ N., 8° 23′ E.]. Another stone (three fragments 4 kg.) was found some 50 km. SSE. of Iférouane and 95 km. from the place of the other fall. Both appear very similar, being 'polychondric miosideric chondrites', consisting mainly of the usual silicates (bronzite and felspar) and containing 1 % nickel-iron and 5·6 % pyrrhotine, but specially characterized by the presence of merrillite, suggesting that they may possibly belong to the same fall. C. A. S.

MOUNTAIN (Edgar D.). *A new meteoric stone from Bowden, Albany, C. P.* South African Journ. Sci., 1934, vol. 31, pp. 225–226.

A meteoric stone, evidently recently fallen, was found in 1907 on the Waterfall farm in the Bowden postal district, 25 miles NNW. from Grahamstown, Cape Province, and was acquired in the same year by the Albany Museum. It is mushroom shaped, with well-marked lines of flow in the crust on the convex surface, and an accumulation of glassy crust on the concave surface. The stone is a typical grey crystalline chondrite. [Size or weight not mentioned.] L. J. S.

Heineman (Robert E. S.). *Petrography of the Roy, Harding County, New Mexico, meteorite.* Amer. Min., 1935, vol. 20, pp. 438–442. [Cf. M.A. **6**–14.].

Chondrules are not visible on the brown and weathered broken surface, but micro-sections show the stone to be a crystalline chondrite with chondrules of the barred olivine, radiating enstatite, and porphyritic types. F. G. Hawley's analysis [M.A. **6**–14] is interpreted as: olivine 36·19, enstatite 31·20, diopside 2·91, maskelynite 8·56, chromite 0·67, ilmenite 0·15, merrillite 0·74, troilite 3·58, oxidation products 15·86 = 99·86. Nickel-iron does not figure in the analysis, although metallic particles are visible on a polished surface. L. J. S.

Perry (Stuart H.) & Wylie (C. C.). *The Athens (Ala.) meteorite.* Popular Astronomy, Northfield, Minnesota, 1935, vol. 43, pp. 331–334, 6 figs. [Cf. M.A. **5**–404.]

From micro-sections this friable stone is described as a grey breccia-like chondrite, with abundant large (1·5 cm.) chondrules of enstatite, crystals of olivine, and little nickel-iron and troilite. Analysis by R. R. Kountz, SiO_2 25·80, Al_2O_3 14·41, Fe_2O_3 43·19, NiO 5·22, MgO 8·51, CaO 1·73, $Na_2O + K_2O$ 1·14 = 100·00 [is obviously incorrect]. L. J. S.

Richardson (Davis P.). *The Fayetteville, Arkansas, meteorite.* Popular Astronomy, Northfield, Minnesota, 1935, vol. 43, pp. 384–385, 1 fig.

Accompanied by detonations and a dull thud a stone of 5 lb. fell at 11.58 a.m. on December 26, 1934, near Fayetteville. It penetrated the soil in a field to a depth of 20 inches, and was lukewarm when dug out. Sp. gr. 3·5. A few days later another stone of 108 grams was found in a new hole 3½ miles to the NE. L. J. S.

Haynes (E. S.). *The Archie, Missouri, meteorites.* Popular Astronomy, Northfield, Minnesota, 1935, vol. 43, pp. 181–184. [Cf. M.A. **5**–404.]

A meteor was observed at 4.30 p.m. on August 10, 1932, over a wide area in Kansas and Missouri. Seven stones with a total weight of 11 lb. 2½ oz. (the largest 8 lb. and the smallest 0·7 oz.) were recovered at Archie in Cass Co. They were found on the surface close to dents only 2 or 3 inches deep. Four stones fell near to persons and were warm when picked up. The material is very friable, and

sists of olivine with a very small amount of nickel-iron; sp. gr.
L. J. S.

ARRA (Cleophas C.) [1866–1935]. *A new South Dakota meteorite.* Science, New York, 1935, new ser., vol. 81, p. 72.

n irregular saddle-shaped mass, with pitted surface, of iron ghing 195 lb. 11 oz. was found while ploughing in 1934 at the l of Black Pipe Creek, 35 miles NE. of Martin in Bennett County. s named the Bennett County meteorite. Analysis gave Fe 94·26, 5·25, Co 0·46, S 0·04 %. Sections show a coarse octahedral cture, with numerous small inclusions of troilite and occasional ll particles of graphite. L. J. S.

INGER (H. H.). *The great meteor of March 24 1933.* Popular Astronomy, Northfield, Minnesota, 1934, vol. 42, pp. 291–306, 6 figs.

large fireball with detonations was observed at 5 a.m. over sas, Colorado, Oklahoma, and New Mexico. Photographs were ined of the fireball and of the luminous trail which persisted for an hour. A few friable fragments were recovered in New Mexico.
L. J. S.

GE-SMITH (T.)]. *A meteorite from New Ireland.* Australian Museum Magazine, 1933, vol. 5, p. 56.

preliminary note on a meteorite which fell at 4.30 p.m. on uary 31, 1933, on Dyarrl Island, near New Ireland, New Guinea. re was a series of explosions and a burst of flame in the sky, and meteor was shattered to pieces. The material of two portions vered (one of 6 oz.) differs in composition and grain size, but mbles that of the stony-iron of Morristown, Tennessee.
L. J. S.

HER (Clyde). *Where a comet struck the earth.* Natural History, Journ. Amer. Mus. Nat. Hist., 1934, vol. 34, pp. 754–762, 11 figs.

A popular account of the Meteor Crater in Arizona. L. J. S.

NNIG (Oscar E.) & BROWN (Robert). *The Odessa, Texas, meteorite crater.* Popular Astronomy, Northfield, Minnesota, 1935, vol. 43, pp. 34–37, 1 fig.

A contoured map shows the crater to be somewhat irregular and ghly circular in outline, with a diameter of about 550 feet. The has an average height of 13 feet above the deepest part and

7 feet above the surrounding plain, but it is much eroded and evidently very old. L. J. S.

Conder (Hartwell). *Darwin glass.* Industrial Australian and Mining Standard, 1934, vol. 89, pp. 329–330.

Thousands of tons of Darwin glass as rounded pebbles and rods resembling stalactites are found over an area of 10 by 6 miles from Macquarie Harbour to Mounts Sorell and Darwin. The country-rocks are granite, conglomerate, sandstone, and limestone. A comparison with the glass from the meteorite craters at Wabar in Arabia and Henbury in Central Australia suggests that the Darwin glass was also formed by the fall of a large meteorite. Denudation is severe on the west coast of Tasmania, and any meteorite craters and meteoric iron may have been destroyed. L. J. S.

Simpson (Edward S.). *Note on an australite observed to fall in Western Australia.* Journ. Roy. Soc. W. Australia, 1935, vol. 21, pp. 37–38.

An ellipsoidal australite weighing 31 grams and measuring 48 × 23 × 20 mm. fell a few feet from four men working in a field at Lake Grace (33° 5′ S., 118° 30′ E.) in the summer of 1932–33. A hissing noise and a thud were heard, and a small hole 12 inches deep was made in the ploughed earth. The different degrees of sand abrasion and the positions in which they are found (on fresh land surfaces and buried to a depth of 10 feet) suggest that australites have fallen at different periods and not all at one time [M.A. **6**–18]. L. J. S.

Lacroix (A.). *Sur la découverte de tectites à la Côte d'Ivoire.* Compt. Rend. Acad. Sci. Paris, 1934, vol. 199, pp. 1539–1542.

The new locality in the Ivory Coast is well beyond the great circle of the earth along which tektite localities were supposed to lie [M.A. **3**–538]. Near the village of Akakoumoekrou on the Comoé river, and some other places within a radius of 40 km. of Ouellé [7° 17′ N., 3° 57′ W.], they have been found sparingly to a depth of one metre in gold-bearing alluvial deposits. The country-rocks are crystalline schists and granites. The tektites are spherical, ovoid, or more or less flattened, with cup-shaped pittings and corrosion grooves. The largest weighs 79 grams. They consist of black glass, sometimes brownish in thin splinters, and contain many spherical bubbles of gas, but no crystallites. One specimen, when struck,

oke with a slight explosion, revealing a central cavity 1 cm. in ameter [cf. MA. **4**–122]. Analyses by F. Raoult:

	SiO_2.	TiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	MnO.	MgO.	CaO.
II.	68·00	0·80	16·46	—	6·08	0·09	3·38	2·00
II.	68·60	0·80	15·80	0·18	6·46	0·06	2·88	1·40
II.	76·56	0·60	11·54	0·17	3·99	0·08	3·60	1·62

	Na_2O.	K_2O.	H_2O+.	H_2O-.	Total.	Free SiO_2 (Calc.).	Sp. gr.	n(Na).
I.	1·45	1·84	0·13	0·14	100·37	38·94	2·517	1·5178
I.	2·35	1·92	—	—	100·45	35·58	2·487	1·5146
I.	1·32	0·82	0·22	0·07	100·59	54·00	2·4	1·4991

L. J. S.

UCRIN (Edmond). *Sur quelques gisements de tectites de l'Indochine du Sud.* Compt. Rend. Acad. Sci. Paris, 1935, vol. 200, pp. 246–248.

Seventeen fresh occurrences of tektites are reported in south Annam, st Cambodia, and Cochin China. They occur on all formations cept recent alluvium, irrespective of age or composition, and are nsistent with a meteoric origin of the tektites, the time of fall ving been not later than that of the formation of the 10–15 metre race of the Quaternary of southern Indo-China. [Cf. M.A. **5**–303.]

C. A. S.

LOUPEK (J.). *Die Herkunft der Moldavite.* Die Naturwissenschaften, 1929, vol. 17, pp. 598–600, 13 figs.

A German abstract of the Czech paper by F. Hanuš [M.A. **3**–537]. oldavites are considered to be of meteoric origin, and the glass is ought to have been fused by friction in the earth's atmosphere. wing to selective absorption from the atmosphere, the determination helium does not give an estimate of their age. L. J. S.

OSICKÝ (Vojtěch). *Jak vznikl povrch vltavínů?* [How has the surface of moldavites been formed?] Příroda, Brno, 1934, vol. 27, pp. 41–49, 3 figs.

An outcrop of perlitic and other obsidian near Seleška in the ešov-Tokaj Mts., eastern Slovakia, shows surface features similar those of moldavites and billitonites—circular pits partly coalescing ad contorted ridges; the shallower hollows following the flow ructure of the obsidian, while the deeper ones are quite irregular

in their arrangement. This sculpturing is due to weathering, and supports the view that the sculpturing of tektites is also due to chemical atmospheric corrosion. Analysis by J. Kokta of the corroded obsidian gave SiO_2 75·75, TiO_2 0·02, Al_2O_3 13·73, Fe_2O_3 1·04, MgO 0·03, CaO 1·25, Na_2O 3·25, K_2O 4·92, P_2O_5 trace, H_2O (+100°) 0·18, H_2O (−100°) 0·09 = 100·26; n_{Na} 1·4867, sp. gr. 2·345. This composition is near to that of normal tektites in SiO_2, Al_2O_3, and CaO, but distinctly higher in Na_2O, and lower in FeO and MgO.

F. S.

Preuß (E.). *Spektralanalytische Untersuchung der Tektite.* Chemie der Erde, 1935, vol. 9, pp. 365–418, 2 pls., 9 text-figs.; Inaug.-Diss. Jena, 1935. [Cf. M.A. **6**–19.]

Full details of the method and results are now given, with sp. gr. and refractive index for several tektites.

	Cr_2O_3 %.	NiO %.
Moldavites, Bohemia (mean)	0·006	0·002
Australites, Australia (mean)	0·013	0·0035
Tektites, north Indo-China (mean) ...	0·012	0·0035
,, south Indo-China (mean) ...	0·03	0·025
,, Billiton and Borneo (mean) ...	0·055	0·035
Darwin glass, Tasmania	0·035	0·04
Silica-glass, Wabar, Arabia...	0·008	0·15
,, Henbury, Australia	0·007	0·12
,, Libyan Desert	0·0006	(<0·001)
Sandstone, Henbury, Australia	0·008	0·004
Clay, Germany	0·022	0·006

No definite conclusions as to origin can be drawn. L. J. S.

Dunn (E. J.). *Australites.* Geol. Mag. London, 1935, vol. 72, pp. 139–140, 1 pl.

Reproduces an old photograph showing a bubble of glass that had been formed on the surface of slag by the falling of a drop of water, and suggests a connexion with australites. L. J. S.

Suess (Franz Ed.). *Australites.* Geol. Mag. London, 1935, vol. 72, p. 288.

In connexion with the preceding note, reiterates the theory that australites are formed by the burning of cosmic masses of silicon [misprinted 'silica'] in the earth's atmosphere [M.A. **5**–303, 406].

L. J. S.

Growth and Corrosion of Crystals.

UCKLEY (Harold E.). *On a cleavage induced by impurity.* Zeits. Krist., 1934, vol. 88, pp. 122–127, 5 figs.

When it is grown from pure solution, potassium sulphate has poor avages on (010) and (001) but none on (100). When alizarin llow 5G (colour index no. 122) is added to the solution, the faces 00) are enhanced and a very perfect cleavage is developed parallel them, though only in those parts of the crystal which have been uated on a (100) face at some period of the crystal's growth.

H. H.

UCKLEY (H. E.). *Examples of the "rutile in quartz" phenomenon in artificial crystals.* Zeits. Krist., 1934, vol. 88, pp. 181–184, 2 figs.

An account of growths of acicular crystals of safranine-resorcinol d safranine-phenol within crystals of potassium sulphate.

H. H.

UCKLEY (H. E.). *The oriented inclusion of impurities in crystals.* Zeits. Krist., 1934, vol. 88, pp. 248–255, 7 figs.

Observations were made on the intergrowth of dyes with crystals K_2SO_4, $KClO_4$, &c. The deposition of colour may be accompanied th growth-retardation, or the colour may be included in small odified crystals growing in parallel position on a larger crystal, or e colour may be deposited on certain faces while other faces suffer odification.

H. H.

UCKLEY (H. E.). *Molecular configuration and its relation to modification of crystal-growth.* Zeits. Krist., 1934, vol. 88, pp. 381–411, 5 figs.

The author's previous work [M.A. **5**–261] on the modification of e habit of $KClO_3$ and K_2SO_4 due to the presence of dyes in the other-liquor has been extended to cover the case of over a hundred es. The planes affected are (011) in $KClO_3$ and (010) in K_2SO_4. sually the deciding factor is the presence of a SO_3Na group in a e, any large molecule containing it having a marked effect on the bit.

H. H.

UCKLEY (Harold E.). *On the mosaic structure in crystals.* Zeits. Krist., 1934, vol. 89, pp. 221–241, 8 figs.

A detailed review of the numerous theories of mosaic structure in ystals. The surface perfection and optical homogeneity of large

numbers of crystals of natural and artificial substances is offered as evidence against the theories of Smekal and Zwicky. The mosaic structure commonly accepted by physicists as a basis for the phenomenon of X-ray primary extinction is also difficult to reconcile with some of the author's observations [following abstract]. F. A. B.

Buckley (Harold E.). *New evidence, setting an upper limit of 500 Å.U. or less, to dimensions of mosaic blocks (if any) in a crystal.* Zeits. Krist., 1934, vol. 89, pp. 410–415, 3 figs.

The banded appearances are described which are seen in the goniometer telescope when reflections from the faces of certain crystals are observed. They are due to optical interference between the rays reflected from the back and front faces of a crystalline plate. H. H.

Frondel (Clifford). *Origin of the segmental coloration of amethyst and smoky quartz.* Amer. Mus. Novitates, 1934, no. 758, 15 pp., 3 figs.

—— *Mineral incrustations upon the edges and corners of crystals.* Ibid., 1934, no. 759, 11 pp., 5 figs.

The symmetrical arrangement of coloured sectors and of encrustations are attributed to the greater adsorptive power of growing edges and corners of crystals. Numerous examples are quoted. [Cf. M.A. **5**–493.] L. J. S.

Frondel (Clifford). *Selective incrustation of crystal forms.* Amer. Min., 1934, vol. 19, pp. 316–329, 4 figs. [Cf. M.A. **5**–493.]

Examples are quoted from the literature and further specimens described with a theoretical discussion. L. J. S.

Frondel (Clifford). *The size of crystals.* Amer. Min., 1935, vol. 20, pp. 469–473.

As a crystal gets bigger the growth tends to become more irregular. Examples are given of large crystals of various minerals in the collection of the American Museum of Natural History. [Cf. M.A. **5**–191, 396.] L. J. S.

Royer (Louis). *De l'orientation des chlorure et bromure de plomb par le mica muscovite.* Compt. Rend. Acad. Sci. Paris, 1935, vol. 200, pp. 567–569. [Cf. M.A. **5**–496.]

When $PbCl_2$ and $PbBr_2$ crystallize on muscovite the crystals are orientated so that (010) of the salt coincides with (001) of the mica

parameter 9·15 Å. of $PbCl_2$, and 9·17 and 4·71 of $PbBr_2$, corresponding with 8·92 and 5·15 Å. of the muscovite. C. A. S.

LB (Georg). *Bemerkungen über Vizinalerscheinungen mit Rücksicht auf die Parkersche Arbeit „Über die morphologische Bedeutung des akzessorischen Stoffansatzes auf Kristallflächen" (1932).* Zeits. Krist., 1933, vol. 86, pp. 1–7, 7 figs.

LLB (G.). *Die Bedeutung der Vizinalerscheinungen für die Bestimmung der Symmetrie und Formenentwicklung der Kristallarten.* Zeits. Krist., 1934, vol. 89, pp. 400–409, 10 figs.

Reiteration, with examples from previous work, of the fact that inal faces are real faces and that their development accords with symmetry of the compound. [M.A. **5**–118, 163, 164, 204.]

F. A. B.

EMMLEIN (G. G.)] Леммлейн (Г. Г.). Шрамовые вицинали на кристаллах аметиста.—LAEMMLEIN (G.). *Narbenvizinalen an Amethystkristallen.* Труды Ломоносов. Инст. Акад. Наук СССР (Trav. Inst. Lomonossoff Acad. Sci. URSS), 1935, no. 6 (sér. cryst.), pp. 13–15 (Russ.), p. 16 (Germ. summary), 4 figs.

LEMMLEIN (Georg). *Narbenvizinalen an Amethystkristallen.* Zeits. Krist., 1934, vol. 88, pp. 470–472, 4 figs.

Amethyst crystals arranged in parallel growth on smoky quartz om the river Adui (Ural) developed vicinal faces on their rhombodral and prism surfaces near their intersections with their ighbours. H. H.

HUBNIKOV (A. V.)] Шубников (А. В.). Исследование вицинальных граней октаэдра квасцов в процессе роста кристаллов.—SCHUBNIKOW (A.). *Étude des faces vicinales de l'octaèdre d'alun au cours de la croissance des cristaux.* Труды Ломоносов. Инст. Акад. Наук СССР (Trav. Inst. Lomonossoff Acad. Sci. URSS), 1935, no. 6 (sér. cryst.), pp. 5–11 (Russ. with Fr. résumé), 7 figs.

HUBNIKOW (A.). *Untersuchung der Vizinalflächen des Alaunoktaeders während der Kristallisation.* Zeits. Krist., 1934, vol. 88, pp. 336–342, 7 figs.

Photographs were taken of the positions of light-signals reflected om the vicinal faces on the octahedral face of growing alum crystals. ney showed that their positions vary continuously with the degree supersaturation of the solution, and that the vicinal faces disappear

when the crystal is in equilibrium with its solution. [Cf. M.A. 3 329, 5–119.] H. H.

[Shubnikov (A. V.)] Шубников (А. В.). Предварительные опыт измерения так называемой кристаллизационной силы.—Schubnikow (A.). *Expériences préliminaires sur les mesures de la forc de cristallisation.* Труды Ломоносов. Инст. Акад. Наук СССР (Trav. Inst. Lomonossoff Acad. Sci. URSS), 1935, no. 6 (sér cryst.), pp. 17–21 (Russ. with Fr. résumé), 4 figs.

Schubnikow (A.). *Vorläufige Mitteilung über die Messung der soge nannten Kristallisationskraft.* Zeits. Krist., 1934, vol. 88, pp. 466–469, 4 figs.

A small glass sphere at the end of a hairpin glass thread was place in contact with a growing crystal of K-Al-alum, and the force o crystallization, amounting to 0·89 g/cm², was determined by measurin the thread's deformation. H. H.

Straumanis (M.). *Wachsende Magnesiumkristalle.* Zeits. Krist. 1934, vol. 89, pp. 487–493, 12 figs.

Magnesium crystals were grown from vapour by sublimation a about 530° C. Besides crystals having the equilibrium form bounde by (0001), (10$\bar{1}$0), and (10$\bar{1}$1) others appeared having some of th faces replaced by curved surfaces, though internally they consist o homogeneous crystalline magnesium. As they continue to grow they develop vicinal faces and finally approach the usual crystallin form. H. H.

Botschwar (A. A.). *Über den Mechanismus der eutektischen Kristalli sation.* Zeits. Anorg. Chem., 1934, vol. 220, pp. 334–336, 5 figs

The mechanism of the process of eutectic crystallization wa studied on mixtures of azobenzene and piperonal. With smal degrees of supercooling, the components crystallize almost inde pendently. With higher supercooling, one component is seen t have a predominating influence; its crystals grow rapidly into th melt, which becomes locally enriched in the more slowly growin component. M. H. H.

Meyer (Julius) & Pfaff (Willy). *Zur Kenntnis der Kristallisatio von Schmelzen.* Zeits. Anorg. Chem., 1934, vol. 217, pp. 257–271, 1 fig.

The crystallization of a melt on cooling is shown to take plac around nuclei of solid impurities. If these are removed by filtratio

nder such conditions as to avoid re-contamination, the melt cannot e made to crystallize by shaking or by a considerable degree of upercooling; in some cases it appears to be impossible to induce rystallization in a perfectly pure (dust-free) melt at any degree of ipercooling, the material passing into a glass. The principal evi-ence for the view that the nuclei consist of solid impurities is that a filtered melt is caused to crystallize by seeding with pure crystals, nd the solid re-melted, the melt so obtained shows no tendency to rystallization; if the nuclei consisted of unmelted crystallites of the ibstance itself [or a persistent 'superstructure'] this should not be ie case. The action of solid impurities as nuclei is probably de-endent on their carrying an oriented layer of molecules adsorbed om the melt. Salol, thymol, benzophenone, *o*- and *m*-cresols, etophenone, piperonal, and guaiacol were employed in this study.

M. H. H.

OETZ (Alexander). *Gruppen-Phänomene in Metallkristallen.* Zeits. Krist., 1934, vol. 89, pp. 310–326.

The hypothesis of a secondary macroscopic structure in a crystal-ne substance is based on the probability of the existence of molecule-mplexes in a liquid near the melting-point. The evidence is viewed with special reference to metallic crystals, and the dis-epancy between coefficients of expansion measured by optical and -ray lattice data is due to the different content of impurities resent in the samples examined. [M.A. **5**–509, 510.] F. A. B.

UERGER (M. J.). *The lineage structure of crystals.* Zeits. Krist., 1934, vol. 89, pp. 195–220, 21 figs.

'Metal crystals grown from melts are invariably filled in dendrites.' ystals of galena from Joplin, Missouri, and pyrite crystals from ba, &c., usually called mosaic crystals are mosaic in cross section ly and are really composed of blocks or 'lineages' proceeding m a common nucleus in sub-parallel growth. Etching experiments, ray primary extinction, gliding and plastic phenomena, and other ta favour a lineage structure theory of all single crystals, not only ndritic crystals. Crystals are internally partitioned by discon-uities in such a way that the entire structure is continuous but anched. Interlineage cavities often contain [and perhaps are due entrapped samples of the solutions from which the minerals have en deposited. F. A. B.

Smekal (Adolf). *Zur Theorie der Realkristalle.* Zeits. Krist., 1934, vol. 89, pp. 386–399.

An account of the structure-sensitive properties of 'real' crystals. The author points out that most of the theories hitherto advanced to explain the difference in behaviour of 'ideal' and 'real' crystals are founded on experiments restricted to one type of artificial or natural compound and are not true for the whole crystal kingdom.

F. A. B.

Stranski (I. N.). *Zur Theorie der isomorphen Fortwachsung (orientierter Ausscheidung) von Ionenkristallen aufeinander.* Zeits. Physikal. Chem., Abt. A, 1929, vol. 142, pp. 453–466, 1 fig.

Stranski (I. N.) & Kuleliew (K.). *Beitrag zur isomorphen Fortwachsung von Ionenkristallen aufeinander.* Ibid., pp. 467–475.

A theoretical consideration of the process of formation of parallel growths between ionic crystals of type AB where the ions A and B (not necessarily monatomic) have different ionic charges in the two salts leads to the conclusion, confirmed by experiment, that a certain definite degree of supersaturation is necessary for one substance to be deposited in parallel growth on another. The parallel growths are principally formed near the edges and corners of the directing crystal. The cases of $NaNO_3$ with $CaCO_3$, $MnCO_3$, and $FeCO_3$ were studied. Parallel growths of NaBr on galena were not obtained, because the necessary supersaturation cannot be attained above 50° C., and below this temperature $NaBr.2H_2O$ is the stable hydrate. It is also shown that it is extremely unlikely that layer crystals, as distinct from parallel growths, would form in such cases. There are difficulties in understanding the formation of true mixed crystals between such pairs of salts, but lamellar mixed crystals are quite possible.

M. H. H.

Fricke (R.). *Periodische (Liesegang'sche) Fällungen in nichtkolloiden Medium.* Zeits. Elektrochem., 1933, vol. 39, pp. 629–641, 11 figs.

Periodic precipitates can readily be obtained in the absence of any colloidal medium provided changes of temperature, which would set up convection currents, are avoided. A periodic precipitate of $Ba(NO_3)_2$ was obtained by diffusion of HNO_3 into $Ba(NO_3)_2$ solution in a capillary tube. The tube was then cut into short lengths, and analyses of the solution in the spaces between the precipitates so obtained. The results agree with the supersaturation theory of the Liesegang phenomenon.

M. H. H.

OLTHOFF (I. M.) & SANDELL (E. B.). *Studies in coprecipitation. VI. Internal structural changes on aging of freshly prepared precipitates.* Journ. Physical Chem., 1933, vol. 37, pp. 723–733.

A study of the effect of ageing on the adsorption of impurities by ystalline precipitates indicates that crystals in general have a mosaic ructure with numerous capillaries and crevices, only a part of hich are in communication with the exterior. M. H. H.

OOD (H.) & TRONSTAD (L.). *Ein Abscheidungsphänomen beim Eintrocknen verdünnter Lösungen.* Kolloid-Zeits., 1934, vol. 68, pp. 333–335, 2 figs.

The formation by evaporation of aqueous solutions of Na_2CO_3, rax, and other salts of a deposit in the form of rings and spirals aring a superficial resemblance to the Liesegang phenomenon is scribed and an explanation given. M. H. H.

UER (Hans). *Zur Theorie der Liesegang'schen Niederschläge.* Kolloid-Zeits., 1933, vol. 64, pp. 181–184, 1 fig.

——. *Übersättigungstheorie der räumlichen und zeitlichen Abstände Liesegangscher Niederschläge.* Zeits. Physikal. Chem., Abt. B, 1934, vol. 27, pp. 145–160, 3 figs.

The supersaturation theory of Liesegang rings is elaborated and proved, and compared with experimental data. M. H. H.

AUGHAN (E. C.). *Mechanism of the Liesegang phenomenon.* Nature, London, 1934, vol. 134, p. 778.

Experiments are described in support of the view that Liesegang ngs are conditioned by the De Broglie wave-length of the diffusing olecules. M. H. H.

CK (Jean) & MENABREA (Jean). *Sur la disposition des faces trièdres obtenus par corrosion d'une lame de quartz.* Compt. Rend. Acad. Sci. Paris, 1935, vol. 200, pp. 1610–1611.

When a plate of quartz cut perpendicular to the optic axis is rroded with hydrofluoric acid triangular pyramids are developed, e angle of elevation of the sides of which is approximately 29°. uartz consists of SiO_2 groups arranged helicoidally so that every urth group is directly above the first at a distance $c = 5{\cdot}38$ Å., while e intersections of the helicoidal axes with the plane perpendicular them form the angular points of a network of equilateral triangles side a 4·89 Å. Now tan 29° = 0·5543, and $c\ 2a = 0{\cdot}5501 = \tan^{-1}$

28° 49′, so that the dimensions of the pyramids are governed by those of the SiO_2 network. C. A. S.

HERBERT (Jean). *Étude des figures de corrosion du verre.* Compt. Rend. Acad. Sci. Paris, 1934, vol. 199, pp. 369–371.

The corrosion figures obtained when a lime-soda glass is corroded with gaseous or aqueous hydrofluoric acid usually have the form of crystals of Na_2SiF_6 or $CaSiF_6$, but differ from these in being isotropic. This is due to the actual formation of such crystals, which rest on the surface of the glass and so protect the areas covered by them from the action of the acid, themselves being subsequently washed away and leaving a trace of their shape. C. A. S.

Pseudomorphs.

FRONDEL (Clifford). *Catalogue of mineral pseudomorphs in the American Museum of Natural History.* Bull. Amer. Mus. Nat. Hist., 1935, vol. 67, pp. 389–426.

A short general bibliography is given. A new classification or descriptive scheme for pseudomorphs is suggested. The origin of substitution and encrustation pseudomorphs is considered from the point of view of colloids, involving adsorption and peptization of the adsorbent. A list is given of 255 pseudomorphs with references to the literature in the case of localities in North America. Several new localities are noted. Pseudomorphs not previously recorded are: brochantite after chessylite, cerussite after fremontite, chalcosine after blende, delafossite after copper (?), grossular after diopside, gypsum after aragonite, magnetite after brookite, malachite after brochantite, pyrite after chalcosine (from Cornwall), quartz after diopside, quartz after prehnite. L. J. S.

COON (J. M.). *Pseudomorphs of cassiterite, etc., after felspar at Wheal Coates, St. Agnes, Cornwall.* Trans. Roy. Geol. Soc. Cornwall, [1934], vol. 26, pt. 6 (for 1933), pp. 297–310, 1 pl., 1 text-fig.

The well-known pseudomorphs of cassiterite and/or mica after porphyritic crystals of felspar occur at the intersection of two lodes of mineralized elvan. In some cases they appear to be later infillings of moulds of the felspar. The felspar of the groundmass of the rock is also replaced by cassiterite. Tourmaline present in the vicinity appears to be a primary constituent of the granitic veins in the slate. L. J. S.

UGH (Frederick H.). *Octahedrite as an alteration product of titanite.* Amer. Min., 1934, vol. 19, pp. 599–602.

Coarse crystals and masses up to 3 lb. of sphene occur with uranice and thucholite in pegmatite at Henvey township, Ontario [A. **4**–502]. They are altered with a green clayey exterior, and hen broken open show a cellular network of quartz encrusted with yriads of minute (0·03–0·16 mm.) crystals of anatase. The crystals c) are black, but greyish-blue by transmitted light. Sometimes e interspaces are filled with calcite, and then a few fragments of tile were detected on the anatase. L. J. S.

ARTZLOW (Carl). *Note on the alteration of galena to anglesite, to cerussite.* Amer. Min., 1933, vol. 18, pp. 174–175.

Galena from residual clay overlying dolomite-rock in Missouri ows banded crusts of earthy grey anglesite, over which is a thin st of cerussite. L. J. S.

HITEHOUSE (F. W.). *On the presence of glendonites in the Dawson valley.* Proc. Roy. Soc. Queensland, 1933, vol. 44, pp. 153–155, 1 pl., 1 text-fig.

Glendonites (pseudomorphs of ferruginous calcite after glauberite) ve been found in soft mudstones of Permo-Carboniferous age at ny localities in New South Wales. They are now recorded from eensland in rocks of the same formation. L. J. S.

NDERSON (Alfred L.). *The incipient oxidation of galena.* Econ. Geol., 1930, vol. 25, pp. 528–542, 9 figs.

— *Notes on the oxidation of jamesonite, sphalerite, and tetrahedrite.* Ibid., 1932, vol. 27, pp. 687–703, 5 figs.

Partly altered specimens from the upper oxidized zone of lodes re examined microscopically in polished sections. The rate of idation and the order in which the different minerals are attacked largely influenced by the difference of electrical potential between ist minerals in contact. The following is the order of increasing bility in the presence of preceding minerals: jamesonite, blende, rahedrite, galena, covelline, chalcopyrite, pyrite. Jamesonite athers more rapidly when in contact with any of the other minerals d at the same time it retards the weathering of these. Pyrite reins after the others are decomposed. L. J. S.

Rock-forming Minerals and Petrology.

Ernst (E.) & Nieland (H.). *Plagioklase von Linosa, ein Beitrag zur Anemousitfrage.* Min. Petr. Mitt. (Tschermak), 1934, vol. 46, pp. 93–126, 9 figs.

Crystals of felspar from the same spot on the island of Linosa, Mediterranean, as those described as anemousite by Washington and Wright (1910) were examined in detail. They show a variation in their optical characters, density, and chemical composition: four analyses range from Ab 61·38, An 34·02, Or 4·60 to Ab 44·62, An 51·55, Or 3·83 mol %; d 2·660–2·693, α 1·5443–1·5589, β 1·5486–1·5621, γ 1·5519–1·5677. The optical data are found to agree with the normal plagioclase series, and there is no need to assume a carnegieite molecule. The assumed anemousite and pacificite from Hawaii [M.A. **4**–398, 508] are not accepted. L. J. S.

Miller (Franklin S.). *Anorthite from California.* Amer. Min., 1935, vol. 20, pp. 139–146, 2 figs.

Anorthite separated from olivine-norite from Pala Mtn., San Diego Co., has sp. gr. 2·759, α 1·574, β 1·582, γ 1·586, 2V 79°; extinction on (001) −35°, on (010) −37°. The optical orientation was completely determined. Analysis by F. A. Gonyer, SiO_2 43·77, Al_2O_3 36·11, Fe_2O_3 0·09, MgO 0·07, CaO 18·73, Na_2O 0·67, K_2O 0·11, H_2O 0·40 = 99·95, corresponds to An 95·13, Ab 5·76, Or 0·56 %.

L. J. S.

Sundius (N.). *Über den sogenannten Eisenanthophyllit der Eulysite.* Årsbok Sveriges Geol. Undersök. (= Avhandl. och Uppsat., ser. C, no. 374), 1932, vol. 26, no. 2, 8 pp., 2 figs.

The 'iron-anthophyllite' occurring in eulysites, described by J. Palmgren from Tunaberg [M.A. **1**–252] and H. Eckermann from Mansjö Mt., Sweden [M.A. **1**–396], is proved to be an orthorhombic pyroxene identical with the iron-hypersthene (Eisenhypersthen) described by M. Saxén (1925) from Vittinge, Finland. Re-examination of the original material from Tunaberg gave α 1·7501, β 1·7601, γ 1·7678, 2V 82°, negative, FeO 41·67 %, sp. gr. 3·85. The mineral shows good partings (100) and (010), but the prismatic cleavage (74–83°) is interrupted. X-ray photographs show it to be distinct from anthophyllite. L. J. S.

ERVAIN (F. de). *Bronzitfels von Loderio (Bleniotal, Tessin).* Schweiz. Min. Petr. Mitt., 1934, vol. 14, pp. 447–449, 1 fig.

This rock, found as loose blocks, consists of radiating aggregates prisms up to 30 cm. long of pale brown bronzite, with some olivine, llage, magnetite, and pyrrhotine. Analysis by J. Jakob of the e bronzite gave SiO_2 56·49, FeO 9·67, MnO 0·06, MgO 33·83, al '100·25', sp. gr. 3·232. The mineral is optically positive with ·662, β 1·667, γ 1·674 (Na), 2V about 80°. It shows some altera- n to bastite and more often to talc. The rock grades into peri- tite.

L. J. S.

E (H. M. A.). *Amphibole from the Purcell sills, British Columbia.* Amer. Min., 1935, vol. 20, pp. 307–309.

Diorite sills up to over a thousand feet thick are intruded into e-Cambrian sediments in the Cranbrook district. Amphibole forms -70% of the rock and is of two types *A* and *B*, which do not occur the same sill. *A* is associated with oligoclase to acid andesine 88–60%) and *B* with basic andesine to acid labradorite (Ab 54– %). Average optical data for type *A* are α 1·661, β 1·677, γ 1·682, 58°, $\gamma : c = 17°$; and for type *B* α 1·641, β 1·657, γ 1·662, 2V 58°, $c = 18°$.

SiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	MgO.	CaO.	$Na_2O + K_2O$.	H_2O (110°).	H_2O (300°).	Total.
42·80	11·26	15·06	14·21	3·82	10·08	1·92	0·16	0·38	99·69
44·66	12·64	15·13	8·85	4·85	10·70	1·80	0·15	0·35	99·13

L. J. S.

MITA (Tôru). *On kaersutite from Dôgo, Oki Islands, Japan, and its magmatic alteration and resorption.* Journ. Shanghai Sci. Inst., Sect. 2, 1934, vol. 1, pp. 99–136, 3 pls., 10 text-figs.

The titaniferous hornblende kaersutite is thought to be characteristic the petrographical provinces of Tertiary alkali effusive rocks. Black phyritic crystals from a basaltic dike at Tikaisi on the island of go have cleavage angle 55° 42·6′, sp. gr. 3·261, α 1·687, β 1·705, ·718 (Na), dispersion F – C 0·019, 2V 80°, negative, $c : \gamma = 4·4°$; ochroism, α pale yellowish-brown, β reddish-brown, γ greenish- wn. Analysis by M. Teshima gave SiO_2 39·78, TiO_2 7·00, Al_2O_3 13, Fe_2O_3 4·61, FeO 7·31, MnO 0·12, MgO 11·01, CaO 10·75, Na_2O 7, K_2O 1·58, H_2O+ 0·37, H_2O- 0·22 = 99·45. Magmatic altera- n of the crystals is of two types: (1) internal alteration to titan- eonite, titanaugite, rhönite, olivine, magnetite, plagioclase, and

glass; (2) a narrow zone of peripheral alteration ('opacitization') to amphiboles of the cossyrite-rhönite group, magnetite, and augite. These alterations and the resorption of the crystals in the teschenitic magma are discussed in detail. L. J. S.

Jugovics (Lajos). *A medvesi bazalttakaró felépítése és kristálytufája.* [Constitution of the basalt plateau of Mt. Medves and its crystal-tuff.] Mat. Természettud. Értesítő, Budapest, 1934, vol. 51, pp. 443–470, 1 pl., 8 text-figs.

Yellowish-green crystals of olivine from the basalt-tuff ('crystal-tuff') of Mt. Medves, com. Nógrád, show the forms *b m s k d e* [Dana's letters]; 2V 89° 4′ (Li), 89° 23′ (Na), 89° 33′ (Tl), β 1·679 (Na), sp. gr. 3·30. Augite crystals (*a b m s o z*) are brownish-green in thin section with 2V 57° 23′ (Na), $c : \gamma = 45° 2' - 47° 5'$, sp. gr. 3·31; analysis by A. Hueber gave SiO_2 45·56, TiO_2 1·87, Al_2O_3 8·15, Fe_2O_3 2·46, FeO 5·45, MnO 0·42, MgO 11·88, CaO 22·84, Na_2O 1·02, K_2O 0·62 = 100·27. Pleonaste occurring as inclusions in the augite, gave Al_2O_3 60·1, Fe_2O_3 4·3, FeO 22·4, MgO 12·0, Cr_2O_3 nil, total '99·8'. V. Z.

Tröger (E.). *Der Gehalt an selteneren Elementen bei Eruptivgesteinen.* Chemie der Erde, 1935, vol. 9, pp. 286–310.

The average contents of Ti, Zr, Cr, V, Ni, Mn, Ba, Sr, Li, P, S, F, Cl, given by published analyses are tabulated for different classes (acid to basic) of igneous rocks. L. J. S.

Tröger (E.). *Quantitative Daten einiger magmatischer Gesteine.* Min. Petr. Mitt. (Tschermak), 1934, vol. 46, pp. 153–173.

Chemical analyses are given of greisen, carbonate-beresite, weisselbergite, sanukite, ornöite, bojite, corsite, lakarpite, alnöite, and olivine-melilitite. L. J. S.

Nemoto (Tadahiro). *Aegirine-augite hyalo-rhyolite from Tokachi, Hokkaido.* Proc. Imp. Acad. Tokyo, 1934, vol. 10, pp. 21–24.

—— *Preliminary note on alkaline rhyolites from Tokati, Hokkaido.* Journ. Fac. Sci. Hokkaido Univ. Sapporo, Ser. 4, 1934, vol. 2, pp. 299–321, 4 pls., 6 text-figs.

The name ôkawaite is given to a glassy rock resembling pitchstone (H_2O 8·54 %) containing phenocrysts of anorthoclase and aegirine-augite, from the Ôkawa river, prov. Tokati; the molecular ratio $Na_2O : K_2O$ is 2·40. Comendite from Maru-yama, prov. Tokati, con-

ains phenocrysts of anorthoclase and aegirine in a cryptocrystalline roundmass, and has the molecular ratio $Na_2O : K_2O$ 1·07. Petrographical descriptions and chemical analyses are given of these rocks.

L. J. S.

ERZAGHI (Ruth Doggett). *The origin of the potash-rich rocks.* Amer. Journ. Sci., 1935, ser. 5, vol. 29, pp. 369–380, 4 figs. Correction, vol. 30, pp. 141–142.

The orthoclase-plagioclase equilibrium diagram [M.A. **5**–67] is no oubt modified by the presence of water and by high pressure, and ne liquid may then contain a higher proportion of orthoclase than a dry melt. Granites and pegmatites may be the result of the queezing out of such a residual magma rich in water and orthoclase. t is also suggested that rocks similar to granite may be produced y the felspathization of metamorphic sedimentary rocks and by the ydrothermal alteration of igneous rocks when there is an increase the K : Na ratio.

L. J. S.

DAMS (Frank D.) & OSBORNE (F. Fitz). *Nepheline syenite from Solwezi, Northern Rhodesia.* Amer. Journ. Sci., 1934, ser. 5, vol. 27, pp. 135–145, 4 figs.

Additional specimens from 40 miles west of Solwezi near the elgian Congo border [M.A. **5**–373] include quartz-mica-schist, capolite-amphibolite, and nepheline-syenites. The scapolite-amphibolite consists of hornblende (55 %), dipyre (25 %), quartz (10 %), oisite, biotite, rutile, &c. A similar rock derived from gabbro near nepheline-syenite contact is known from Ontario. The nepheline-yenites range from grey to dark red with blue sodalite, green yroxene, and yellow cancrinite. An analysis is given. Further ention is made of the nepheline-syenite from Loangwa river near ne Nyasaland border.

L. J. S.

ITCHEN (C. Stanfield). *The pegmatites of Fitchburg, Massachusetts.* Amer. Min., 1935, vol. 20, pp. 1–24, 13 figs.

The pegmatites occur in granite as veinlets, lenses, or pipes, and iotite, tourmaline, beryl, sphene, and orthite types are distinguished. he first four types represent successive residual fractions from the ystallization of the granite; while the last and later calcite veins epresent a hydrothermal stage. Descriptions are given of the veral minerals.

L. J. S.

Landes (Kenneth K.). *Age and distribution of pegmatites.* Amer. Min., 1935, vol. 20, pp. 81–105, 153–175, 6 figs. [Cf. M.A. **5**–368.]

A useful compilation on the occurrence of pegmatites. Examples are quoted of pegmatites of pre-Cambrian to Tertiary age. Their geographical distribution is given in detail with numerous references to the literature. On the maps of six continents are plotted the localities of complex acid, intermediate, and basic pegmatites. L. J. S.

Wheeler (E. P. 2nd). *An amazonite aplite dike from Labrador.* Amer. Min., 1935, vol. 20, pp. 44–49.

A 5-foot dike in syenite was found at Long Tickle on Adlavik island. The rock is fine-grained and very pale green in colour. It consists of amazonite (48 %), albite (28·5), quartz (19), zinnwaldite (3), topaz (1 %), with little fluorite and apatite. The chemical composition is unusual; analysis by M. G. Keyes gave SiO_2 73·25, TiO_2 nil, Al_2O_3 15·23, Fe_2O_3 0·06, FeO 0·52, MnO 0·02, MgO 0·06, CaO 0·03, Na_2O 6·35, K_2O 3·95, Li_2O n. d., P_2O_5 0·03, H_2O+ 0·16, H_2O- 0·12 = 99·78, sp. gr. 2·642. L. J. S.

[Bezborodko (N. I.)] Безбородько (Н. И.). К петрогенезису темноцветных пород Подолии и соседних районов. Bezborodko (N.). *Sur la pétrogenèse des roches foncées de la Podolie et des régions voisines.* Труды Мин. Инст. Акад. Наук СССР (Trav. Inst. Min. Acad. Sci. URSS), 1931, vol. 1, pp. 127–158 (Russ.), 158–159 (French résumé), 2 pls., 2 text-figs.

—— Безбородько (М. І.). Сабаровіт—крайній кислий член піроксенотоналітового ряду на Поділлі (бугітова серія). Bezborodko (N.). *Sabarovite, the extreme acid member of the pyroxene-tonalite range in Podolia (bugite series).* Геологічний Журнал, Всеукраїнська Академія Наук, Київ (Journal of Geology, All-Ukrainian Academy of Sciences, Kyiv), 1934, vol. 1, no. 1, pp. 61–90 (Ukrainian), 90–94 (English summary), 2 figs.

Rocks of the bugite series occupy a wide area in Podolia in the neighbourhood of the Bug river. They are dark-coloured, fine-grained rocks consisting essentially of plagioclase (oligoclase to andesine), hypersthene, and quartz; and they differ from charnockite in the rarity or absence of orthoclase. They show a wide range in composition:

	SiO_2.	Pyroxene.	K_2O.
Epibugite	66–72 %	0–8%	less
Mesobugite ...	58–66	5–20	than
Katabugite ...	50–58	25–40	2 %

The most acid member is called sabarovite, from the village abarovo, south of Vinnitza on the Bug. Analysis of this gave SiO_2 71·69, Al_2O_3 13·72, Fe_2O_3 2·10, FeO 2·90, MgO 1·21, CaO 2·50, Na_2O 4·48, K_2O 1·20, H_2O 0·55 = 100·35. It is compared with soda-lamellite and quartz-monzonite. L. J. S.

OLLINS (W. H.). *Life-history of the Sudbury nickel irruptive. I. Petrogenesis.* Trans. Roy. Soc. Canada, 1934, ser. 3, vol. 28, sect. 4, pp. 123–177, 14 figs. [Cf. M.A. **4**–227.]

A review is given of the history, with many chemical analyses nd density determinations, of the nickel-bearing norite and of the ansition rocks into the overlying micropegmatitic granite. The hole complex is regarded as a single intrusion with subsequent fferentiation. L. J. S.

ACROIX (Alfred). *Volcanisme et lithologie.* Mission au Tibesti (1930–1931) by M. Dalloni. Mém. Acad. Sci. Paris, 1934, vol. 61, pp. 169–366, pls. 1–6, 16–20, 2 maps, 1 text-fig.

A review of the volcanicity and an account of the petrography, pported by numerous chemical analyses, of the volcanic rocks and ssociated intrusions, probably Quaternary, and also of a group of der dike-rocks cutting the sedimentary rocks of Tibesti. The older ke-rocks are classified as grorudite, nordmarkite, sölvsbergite, achyte, nepheline-syenite, essexite, berondrite, luscladite, gabbro, onolite (tinguaite and murite), camptonite, and monchiquite. urite is a variety of phonolite named by the author in 1929, from uri Point, Raratonga, Cook Archipelago.

The volcanic rocks which form the main subject of the memoir mprise : rhyolites, including comendite and pantellerite, but also plagioclase- and hypersthene-bearing type (dellinite) and the corre-onding obsidians, tuffs, and breccias; alkali-trachytes, latite, oreite (intermediate between trachyte and andesite), phonolites, acitoids, andesites, basalts, basanitoids, and ankaramite. Certain icrogranular rocks associated with the volcanics are also described, ne of which, a microsyenite, contains anorthoclase phenocrysts re-mbling those of the rhomb-porphyries. They show the forms (110), c (001), x ($\bar{1}01$). D 2·625, α 1·539, γ (Na) 1·543. Extinction n (001) 1°, on (010) from 3 to 8°. Composition SiO_2 65·26, Al_2O_3 20·60, e_2O_3 0·12, FeO 0·38, CaO 3·06, Na_2O 6·29, K_2O 4·28, H_2O+ 0·16, $_2O-$ 0·14, equivalent to Or 27·20, Ab 56·83, An 15·96.

The final chapter compares the volcanic rocks of Tibesti with

others from various districts in the Sahara and north-eastern Africa, and besides containing much that is new it gives a useful summary of published work on volcanic rocks in these parts of Africa.

In a microgranite from Mounio (Munio) occurs a mineral, first noticed in 1905. This is more fully described, and the name goureite is proposed for it. Properties given are: uniaxial, negative, ϵ 1·61, ω 1·63 about, $\omega - \epsilon$ 0·025; colourless in thin section, but straw-yellow in hand-specimens. W. C. S.

Lombaard (B. V.). *On the differentiation and relationships of the rocks of the Bushveld complex.* Trans. Geol. Soc. South Africa, 1935, vol. 37 (for 1934), pp. 5–52, 1 pl., 7 text-figs.

A general discussion of the petrology of the Bushveld complex arises out of the detailed mapping of an area in the Lydenburg district. New observations are recorded concerning a transitional relationship between the red granite, the granophyre, and the felsites, the argument being supported by a number of chemical analyses. A careful study was made of the composition of the plagioclase and the pyroxene in the norite. The plagioclase varies from An_{45} to An_{85}, the proportion of albite generally increasing from the base of the complex upwards, although the increase is an oscillating rather than a progressive one. The pyroxene is sometimes bronzite, sometimes hypersthene, sometimes a diallage belonging to the diopside-hedenbergite series and apparently holding little or no alumina. It is shown that monoclinic pyroxene dominates over rhombic pyroxene in the upper part of the lopolith, and that the name gabbro is more appropriate than norite for such rocks. The pyroxene of the pyroxenites has the same composition as that of the associated gabbros and norites, which gives support to the view that these pyroxenites were formed by crystal-settling. The magma-types recognized in the Bushveld complex are compared with those in the British Tertiary province. S. J. S.

Suzuki (Jun). *Metamorphosed calcareous concretions in the hornfels at the southern coast of Tokati province, Hokkaido.* Journ. Fac. Sci. Hokkaido Univ. Sapporo, Ser. 4, 1934, vol. 2, pp. 323–338, 3 pls., 3 text-figs.

Biotite- and biotite-cordierite-hornfels, representing metamorphosed sediments near a granite contact, show spots up to 10 cm. in diameter or pipe-like bodies up to 50 cm. long. The central portion is greyish-white and the marginal zone greyish-green to dark-green.

ey are composed of quartz, plagioclase, clinozoisite, and diopside, th hornblende and biotite in the marginal zone, while the sur- nding hornfels contains quartz, plagioclase, biotite, and cordierite. ots farther from the granite contact contain some residual calcite.
L. J. S.

ZUKI (Jun). *On some soda-pyroxene and -amphibole bearing quartz schists from Hokkaido.* Journ. Fac. Sci. Hokkaido Univ. Sapporo, Ser. 4, 1934, vol. 2, pp. 339–353, 5 figs. [Cf. M.A. **4**–402.]

Aegirine-augite quartz-schists with either riebeckite or glauco- ane are described. L. J. S.

YLOR (James H.). *A contact metamorphic zone from the Little Belt Mountains, Montana.* Amer. Min., 1935, vol. 20, pp. 120–128, 2 figs.

At a gabbro-limestone contact the labradorite of the gabbro is re- ced by orthoclase. Next the gabbro is a zone of dark silicates nsisting mainly of pyroxene, prehnite, and calcite, with epidote, thoclase, &c., and in one type merwinite and gehlenite. An outer ne of light silicates consists of calcite, idocrase, and garnet, with llastonite, &c., and in one variety gehlenite and scawtite (a new ality for this mineral [Min. Mag. **22**–222.]) L. J. S.

RNER (F. J.). *Contribution to the interpretation of mineral facies in metamorphic rocks.* Amer. Journ. Sci., 1935, ser. 5, vol. 29, pp. 409–421.

The various assemblages of minerals that are stable under different nditions of temperature and pressure are considered. The presence water also has an important influence, and different cases are ven by rising and falling temperature. Green-schists, consisting of lorite, epidote, and albite, are specially considered. L. J. S.

PLIN (Germaine A.). *The petrology of the Hartley district. II. The metamorphosed gabbros and associated hybrid and contaminated rocks.* Proc. Linn. Soc. N.S.W., 1933, vol. 58, pp. 125–158, 2 pls. (map), 4 text-figs.

The second of a series of papers describing the petrology of the rtley district, some seventy miles west of Sydney, New South ales. An earlier intrusion of gabbro was closely followed and veloped by quartz-mica-diorite and the gabbros have thereby ffered metamorphism and hybridization. In the course of the

study of these rocks the author has made many observations on the alteration of the felspars during metamorphism and has noted two types: a greyish clouding produced by minute inclusions, and a clearing accompanied by tiny granular inclusions. These are essentially the same phenomena, the inclusions which cause the clouding increasing with the grade of metamorphism. A. G. MacGregor's paper on this subject (Min. Mag., 1931, vol. 22, p. 524) is discussed.

W. C. S.

Sander (Bruno). *Typisierung von deformierten Tonschiefern mit optischen und röntgenoptischen Mitteln.* Zeits. Krist., 1934, vol. 89, pp. 97–124, 14 figs.

The stratum-structure of various clay-slates is deduced from the orientation of mica flakes and quartz crystals by the usual Fedorov and X-ray methods. The distortion of fossils in calcareous sediments confirms the evidence similarly obtained from the orientation of included mineral grains. F. A. B.

Zeolites.

Tiselius (Arne) & Brohult (Sven). *Sorption von Wasserdampf an Chabasit bei verschiedenen Temperaturen.* Zeits. Physikal. Chem., Abt. A, 1934, vol. 168, pp. 248–256, 4 figs.

The vapour-pressure of chabazite from Klaksvik, Faeroe Is., SiO_2 48·78, Al_2O_3 18·69, CaO 8·62, Na_2O 1·39, K_2O 0·34, H_2O 22·25 = 100·07, was determined at a series of temperatures and pressures by an isothermal method. The Langmuir isotherm is obeyed at low temperatures, but not above about 80° C. The heat of hydration ranges from $1{\cdot}51 \times 10^4$ to $1{\cdot}85 \times 10^4$ cals. per gram-mol. H_2O, and shows a maximum near 20 % H_2O calculated on the anhydrous weight [= 9 mol. H_2O per unit cell approx.]. This maximum was confirmed by study of another specimen of different composition (CaO 7·8 %) by isohydric methods; the heats of hydration for this specimen were about 1000 cals. lower throughout. M. H. H.

Tiselius (Arne). *Diffusion of water in a zeolite crystal.* Nature, London, 1934, vol. 133, pp. 212–213, 2 figs.

—— *Die Diffusion von Wasser in einem Zeolithkristall. Ein Beitrag zur Frage der Beweglichkeit adsorbierter Moleküle.* Zeits. Physikal. Chem., Abt. A, 1934, vol. 169, pp. 425–458, 13 figs.

Utilizing the changes in birefringence and extinction-angle with change of water content, the process of rehydration of a dehydrated

landite crystal has been followed. The velocity of diffusion of re-entering water is nil normal to the cleavage plane *b* (010), le in directions parallel to the cleavage plane it shows a marked imum normal to the face *c* (001). The values of the diffusion stant in several directions and at various water contents and peratures were determined. M. H. H.

ESHIMA (Jitsusaburo) & HEMMI (Hachiro). *Sorption of gas by Mineral. IV. Zeolites and bentonite.* Bull. Chem. Soc. Japan, 1934, vol. 9, pp. 27–41, 4 figs. [Cf. M.A. **5**–240.]

A study of the absorption of ammonia, carbon dioxide, sulphur xide, acetylene, oxygen, and hydrogen by partially dehydrated ontite, stilbite, mordenite, natrolite, inesite, and bentonite, all m named Japanese localities. Ammonia is absorbed in considerable ount by all these minerals but not by analcime; the other gases are y absorbed in appreciable amount by bentonite and mordenite. tonite is regarded as a case of pure adsorption, like silica gel; rdenite as forming solid solutions, like chabazite; the other lites are believed to combine chemically with ammonia.

M. H. H.

BINOWITSCH (E.) & WOOD (W. C.). *Ionic exchange and sorption of gases by chabazite.* Nature, London, 1933, vol. 132, p. 540, 2 figs.

Chabazite from Rübendörfel, Aussig, Bohemia, was treated with utions of K, Na, Ca, Sr, Ba, Cd, and La salts, and the absorption hydrogen and nitrogen at −190° C. by the dehydrated base-change products studied. Only small differences were found tween the absorption by the base-exchange products containing alent ions. The sodium compound showed a very much smaller sorption of nitrogen than the calcium compound, but the absorption hydrogen was unaffected; the potassium compound, on the other nd, had practically no absorptive power for either nitrogen or drogen. M. H. H.

BINOWITSCH (E.) & WOOD (W. C.). *Über die Elektrizitätsleitung in Zeolithen.* Zeits. Elektrochem., 1933, vol. 39, pp. 562–566, 5 figs.

The electrical resistance of zeolites varies greatly with the locality origin (10^7 and 10^{10} ohm per cm. cube for chabazite from the eroe Is. and Nidda respectively), but is regarded as a definite

quantity for material of a given origin. The resistance decrease with increasing perfection and purity of the crystals; increases with loss of water; and decreases with rise of temperature under conditions which exclude loss of water. Chabazite-ammonia has a lower resistance than normal chabazite. The conduction is electrolytic in nature, and the cations are probably the current carriers; on discharge they react with the water, so that the sole demonstrable products of electrolysis are hydrogen and a little alkali. [Cf. M.A. **2**–300; Min. Mag. **23**–282.] M. H. H.

Gruner (Erhard). *Untersuchungen an Alkali-Aluminium-Silikaten. VIII. Die Gültigkeit der Hüttig'schen Gleichung bei Permutiten.* Zeits. Anorg. Chem., 1934, vol. 221, pp. 142–148.

The vapour-pressure equation proposed for zeolites by G. F. Hüttig (1920) was modified in accordance with the author's view that the permutites contain water of constitution as well as 'osmotically' bound' water. The modified equation was tested experimentally and found fairly satisfactory. M. H. H.

Chrobak (Ludwik). *Zależność prężności pary wodnej desminu od zawartości wody i od temperatury.—Die Abhängigkeit der Wasserdampfspannung des Desmins vom Wassergehalt und von der Temperatur.* Bull. Internat. Acad. Polonaise, Ser. A, 1925, pp. 333–345, 2 pls., 2 text-figs.

A thorough study by an isohydric method of the vapour pressure of an analysed specimen of stilbite from Berufjord. The results are regarded as in agreement with Tschermak's formula $CaAl_2Si_2O_8$. $H_8Si_4O_{12}.H_2O.2aq$ for stilbite. M. H. H.

Dominikiewicz (Mieczysław). *O pewnych reakcjach natrolitu naturalnego. (Przyczynek do poznania rodnika natrolitowego glinokrzemianów).—Ueber einige Natrolitreaktionen. (Ein Beitrag zur Kenntnis des Natrolitradikals einiger Alumosilikate).* Arch. Min. Tow. Nauk. Warszaw. (Arch. Min. Soc. Sci. Varsovie), 1933, vol. 9, pp. 116–125 (Polish), pp. 126–127 (German résumé).

By base-exchange from natrolite and from dehydrated natrolite, hydrous and anhydrous silver-natrolites are obtained. Ammonium salts react with silver-natrolite to give ammonium-natrolite, $4H_4[H_2(NH_4)_2]Al_4Si_6O_{22}.3NH_3$, in which part of the ammonia replaces water of crystallization. Sodium 'hydrokaolinate' gives a silver derivative by base-exchange. M. H. H.

Thugutt (Stanisław Józef). *O ptylolicie z Mydzka na Wołyniu.—Sur la ptilolite de Mydzk en Volhynie.* Arch. Min. Tow. Nauk. Warszaw. (Arch. Min. Soc. Sci. Varsovie), 1933, vol. 9, pp. 99–102 (Polish), pp. 103–104 (French résumé).

Ptilolite occurs at Mydzk in Volhynia, Poland, in fissures in basalt, with quartz, quartzine, and chlorite. It has sp. gr. 2·08, n between 1·472 and 1·495, birefringence very weak, positive. Analysis gave SiO_2 67·00, Al_2O_3 10·68, Fe_2O_3 1·01, MgO 0·02, CaO 2·46, Na_2O 0·74, K_2O 5·32, H_2O 12·95, total 100·18. M. H. H.

Kratochvíl (František). *Příspěvek k poznání českých prehnitů a zeolitů.* [Contribution to the knowledge of Bohemian prehnites and zeolites.] Časopis Národního Musea, Praha, 1933, vol. 107, pp. 36–44, 2 figs.

Secondary prehnite, analcime, natrolite, thomsonite, and calcite are present in Silurian diabases at Budňany, S.W. of Praha. The prehnite (*c m a b*) forms parallel growths in the direction of the *a*-axis, along which is a central core of darker prehnite, possibly representing a pseudomorph after acicular crystals (of natrolite ?). Clear, colourless crystals of analcime (n_{Na} 1·485) gave I, and natrolite (α 1·478, β 1·480, γ 1·491, $2V_{Na}$ 58°) gave II. The sp. gr. of this analcime is unusually high : milky-white crystals from the same locality have sp. gr. 2·240.

	SiO_2.	Al_2O_3.	Fe_2O_3.	MgO.	CaO.	Na_2O.	K_2O.	H_2O.	Total.	Sp. gr.
I.	56·49	22·35	0·21	trace	0·16	11·95	0·44	8·69	100·29	2·256
II.	46·42	27·27	0·59	trace	1·04	14·43	0·47	9·64	99·86	2·252

F. S.

Kratochvíl (František). *Prehnity čáslavského okolí.* [Prehnites from the environs of Čáslav.] Rozpravy České Akad., Class II, 1934, vol. 44, no. 17, 22 pp., 1 fig.

Prehnite occurs in cavities in amphibolite near Čáslav in eastern Bohemia, where, with earlier clinozoisite and later zeolites, chlorite, and calcite, it is of hydrothermal origin. In the country-rock itself prehnite originates from amphibole, plagioclase, clinozoisite, and rarely from diopside. Analyses are given of three types of material from Markovice. I, white to very pale pink, with laumontite and calcite. II, compact, yellowish-green, with albite. III, spherulitic comb-like aggregates, the commonest type, with earlier clinozoisite and later analcime, natrolite, and calcite. Optical data were also determined for prehnite from Radauthal (Harz), Oberstein (Rhine),

and Dumbarton: these and others collected from the literature show no interdependence of the optical data with the percentage of Fe_2O_3, FeO, MnO, or H_2O, nor with the colour of the material. Dehydration curves are given. The optical properties begin to show a change at about 600° C. In the dehydrated material α and β fall to about 1·57, with diminished birefringence, and the cleavage flakes become aggregates.

	SiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	MnO.	MgO.	CaO.	Na_2O.	K_2O.	H_2O.	Total.
I.	43·07	23·13	1·53	0·50	0·03	0·11	26·98	0·14	0·14	4·83	100·46
II.	42·29	24·68	0·68	0·68	0·03	0·23	27·02	0·08	0·17	4·58	100·44
III.	42·76	24·83	0·13	1·12	0·05	0·07	26·84	0·03	0·18	4·24	100·42

		Red.		Yellow.			Green.		2V yellow.
	Sp. gr.	α.	β.	α.	β.	γ.	α.	β.	
I.	2·865	1·618	1·628	1·610	1·618	1·635	1·603	1·612	69° 0′
II.	2·925	1·619	1·626	1·615	1·622	1·637	1·610	1·615	68 50
III.	2·928	1·618	1·626	1·613	1·620	1·635	1·606	1·612	69 30

F. S.

Hey (M. H.) & Mourant (A. E.). *Epistilbite from Jersey.* Bull. Soc. Jersiaise, 1933, vol. 12, p. 104.

Epistilbite occurs in a pre-Cambrian mudstone in a quarry near the Dannemarche reservoir, St. Lawrence valley, Jersey. M. H. H.

Reichert (Róbert) & Erdélyi (János). *A Csódi-hegy ásványairól.—Über die Minerale des Csódi-Berges.* Mat. Természettud. Értesítő, Budapest, 1934, vol. 51, pp. 425–441 (Hung.), p. 442 (Germ. résumé), 1 pl., 4 text-figs.

Reichert (R.) & Erdélyi (J.). *Über die Minerale des Csódi-Berges bei Dunabogdány (Ungarn).* Min. Petr. Mitt. (Tschermak), 1935, vol. 46, pp. 237–255, 10 figs.

Chabazite crystals show the forms *e s* [Dana's letters] and have *n* 1·485, optically positive; anal. I of colourless to white, II of yellowish-rose crystals. The phacolite variety shows *r e s t*, with *n* 1·484, opt. +. Analcime crystals (*n a*) with *n* 1·485 gave III. Stilbite crystals (*m c b f*) with α 1·494, γ 1·504 gave IV. Calcite crystals of different types are described.

	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	SrO.	BaO.	MgO.	Na_2O.	K_2O.	H_2O.	Total.
I.	48·54	19·54	trace	7·46	0·54	0·24	nil	1·50	0·67	21·94	100·43
II.	50·17	18·24	0·19	7·30	0·47	0·17	trace	1·55	0·17	22·05	100·31
III.	55·64	25·42	trace	0·11		nil	nil	10·89	0·12	8·50	100·68
IV.	54·59	17·93	0·39	6·92	0·28	0·31	trace	1·80	0·10	18·27	100·59

V. Z.

ALMERS (R. O.). *Stilbite collecting at Garrawilla.* Australian Museum Mag., 1934, vol. 5, pp. 240–245, 6 figs.

Stilbite is plentiful in weathered vesicular basalt at this locality New South Wales. L. J. S.

'NHAM (Kingsley C.). *Crystal cavities in lavas from the Hawaiian Islands.* Amer. Min., 1933, vol. 18, pp. 369–385, 1 fig.

In veins and cavities in a nepheline-melilite-basalt at Moiliili arry, Honolulu, there occur nepheline (anal. I, ω 1·542, ϵ 1·537), gite (α 1·699, β 1·701, γ 1·721, 2V 60°), melilite (ω 1·635, ϵ 1·631), utite (ω 1·637, ϵ 1·629), magnetite, phillipsite (anal. II, α 1·493, 1·497, γ 1·500), chabazite (anal. III, n 1·485), hydronephelite al. IV, α' 1·491, γ' 1·499), allophane, and calcite. At Alexander n, Kauai, in cavities of an ankaratrite occur olivine (α 1·663, 1·680, γ 1·701, 2V 90°), augite (n 1·69), stilbite (α 1·495, β 1·498, 1·501), gismondine (α 1·538, β 1·543, γ 1·548), pseudomorphs of dronephelite (α' 1·491, γ' 1·500) after nepheline, allophane (anal. n 1·49), and aragonite. In a brown amygdaloidal basalt at Lana- i hills, Hawaii, occur quartz, epistilbite (α 1·505, β 1·515, γ 1·519), mmontite (anal. VI, α 1·511, β 1·518, γ 1·522), heulandite (anal. I, α 1·501, β 1·504, γ 1·509), ptilolite (anal. VIII, α' 1·475, γ' 478), and nontronite (n 1·56). At Salt Lake Crater, laumontite d nontronite occur in an agglomerate. An explosion block pted in 1924 from Halemaumau, Hawaii, has an ophitic texture, th labradorite, augite, and haematite, and contains cristobalite 1·485) in cavities. Laumontite and ptilolite from Kailua gave al. IX and X. The paragenesis of the several occurrences is cussed. The material was collected and the analyses made by the e A. S. Eakle [1862–1931].

	SiO_2.	Al_2O_3.	CaO.	Na_2O.	K_2O.	H_2O.	Total.
I.	41·27	32·38	1·33	16·95	4·65	—	'99·46'*
II.	42·34	22·31	3·90	4·26	6·78	19·70	99·29
III.	47·00	21·64	10·13	—	—	20·98	99·75
IV.	43·31	29·92	3·27	11·66	—	12·38	100·54
V.	30·2	40·3	—	—	—	27·6	99·9†
VI.	52·34	22·27	10·83	—	—	14·06	99·50
VII.	57·28	17·76	7·18	2·95	—	15·42	100·59
VIII.	65·56	10·55	5·46	3·07	—	15·31	99·95
IX.	52·30	23·38	10·36	—	—	14·26	100·30
X.	65·66	10·77	5·43	3·90	—	14·40	'100·18'

* Also 1·08 % Fe_2O_3. † Also 1·8 % MgO.

M. H. H.

Inuzuka (Hideo). *Apophyllite from the Kamioka mine, Hida.* Journ. Geol. Soc. Tokyo, 1933, vol. 40, pp. 645–654 (Japanese); abstract in Japanese Journ. Geol. Geogr., 1934, vol. 11, abstracts p. 10.

Crystals show the forms *a c p*. Refractive indices for Na-light at 18° C., ω 1·5335–1·5339, ϵ 1·5359. Analysis gave SiO_2 52·76, Al_2O_3 1·52, CaO 25·66, $K_2O + Na_2O$ 2·80, H_2O 15·85 = 98·59. L. J. S.

Henderson (E. P.) & Glass (Jewell J.). *Additional notes on laumontite and thomsonite from Table Mountain, Colorado.* Amer. Min., 1933, vol. 18, pp. 402–406.

Golden-brown laumontite from the quarry on the south face of North Table Mountain, Golden, Colorado, had α 1·504, β 1·514, γ 1·516, 2V 25–35°, negative, $\rho > v$, $\gamma : c = 30–36°$, and gave SiO_2 50·82, Al_2O_3 20·06, Fe_2O_3 2·18, CaO 12·14, MgO 0·02, Na_2O 0·31, K_2O 0·22, H_2O 14·87, V_2O_3 nil, total '99·97'%. Thomsonite, as small, brown spherules associated with the laumontite, had α 1·518, β 1·521, γ 1·531, 2V 54°, positive, $\rho > v$, optic axial plane $\parallel c$, $Bx_a \perp b$, and gave SiO_2 38·55, Al_2O_3 29·08, Fe_2O_3 1·89, CaO 12·14, MgO 0·04, Na_2O 4·38, K_2O 0·44, H_2O 14·02, total '100·77'. Thomsonite, with 2V 72° and α 1·513, β 1·519, γ 1·527, was also present.

M. H. H.

Chappell (Walter M.). *Paulopost stilbite in the Camas Land sill, Chelan County, Washington.* Amer. Min., 1933, vol. 18, pp. 440–444, 3 figs.

The latest products of crystallization of the Camas Land gabbro sill are quartz, calcite, and stilbite. The stilbite has also partially replaced plagioclase. It has good *b* and imperfect *a* cleavages, and its optical characters are: α 1·487, β 1·498, γ 1·50, 2V 48°, neg., $a : c = 7°$. A short description of the rock is given. M. H. H.

Wyart (J.). *Recherches sur les zéolites.* Bull. Soc. Franç. Min., 1933, vol. 56, pp. 81–187, 8 pls., 9 text-figs. [Cf. M.A. **5**–354.]

Clays.

Marshall (C. E.) & Gupta (R. S.). *Base-exchange equilibria in clays.* Journ. Soc. Chem. Ind. London, 1933, vol. 52, pp. 433T–443T, 2 figs.

A detailed study of several base-exchange reactions with beidellite and montmorillonite of known origin and particle size shows that

one of the equations proposed hitherto correlates the quantitative ata satisfactorily. Montmorillonite is a fairly strong electrolyte, eidellite only a weak one. The peculiarities of electrolytic dissocia- on in the colloidal clays are discussed. M. H. H.

AVER (H.) & MARSHALL (C. E.). *The rôle of aluminium in the reactions of the clays.* Journ. Soc. Chem. Ind. London, 1934, vol. 53, pp. 750–760.

Whereas $LaCl_3$, $FeCl_3$, and $[Co(NH_3)_6]Cl_3$ give normal base-change reactions with montmorillonite and beidellite clays, Cl_3 does not. The liberation of Al from unsaturated [acid] clays nd neutral salt solutions is due to direct exchange, and in all cases ydrogen is exchanged simultaneously. The reduction in base change capacity observed when clays are treated with aluminium lts is due to precipitation of $Al(OH)_3$ within the clay micelles. The servations are discussed theoretically and it is concluded that ydrogen clays are unstable and tend to break down spontaneously to mixed Al–H clays; in these a part of the aluminium of the ionic lattice has been transferred to cation positions, being replaced y hydroxyl groups. M. H. H.

ARSHALL (C. E.). *Mineralogical methods for the study of silts and clays.* Zeits. Krist., 1935, vol. 90, pp. 8–34.

Methods for the identification of the smaller mineral particles esent in soils are discussed. With grains larger than 0·001 mm., e usual mineralogical methods employing the microscope and eavy liquids are available, and a determinative table is given for inerals known to exist in soils in the fraction 0·020 to 0·001 mm. ith particles smaller than 0·001 mm., these methods fail. It is, owever, still possible to determine the density, the refractive index, nd a birefringence. For the density, heavy liquids are used, and dimentation speeded with a centrifuge. The refractive index is etermined by an immersion method, using a dark-ground condenser. he birefringence is determined by measuring the optical path-differ- ce of a column of suspension of known concentration in which the rticles are oriented by an electric field. The birefringence so etermined is not necessarily the maximum birefringence, but under itable conditions is a characteristic constant of the mineral. Four ays examined proved to be heterogeneous as regards the fraction 0·001 mm. size, and it appears probable that a number of clay inerals exist which have not yet been properly characterized.

Eye-strain in refractive index determinations by the immersion method is minimized by a projection method. M. H. H.

Urbain (Pierre). *Sur la séparation des divers constituants des argiles.* Compt. Rend. Acad. Sci. Paris, 1934, vol. 198, pp. 964–967, 1 fig.

Electrolytes are removed by suspension in water and thrice centrifuging. The solids are then suspended in water in an inverted cylindrical vessel closed by a cap, and subjected to a vertical electric field of about 100 volts per cm., positive below, the negative colloids being subsequently separated from the crystalline solids (with which they have settled) by a similar method, while the positive colloids remain in suspension. All traces of electrolytes are finally removed by electrodialysis, and four fractions are obtained: crystalline solids, positive colloids (metallic hydroxides), negative colloids (Al silicates), and a saline solution. C. A. S.

Dreyfuss (Maurice). *Méthodes pour la séparation de la fraction argileuse des roches sédimentaires.* Compt. Rend. Acad. Sci. Paris, 1934, vol. 199, pp. 1631–1633.

An amount of the rock containing at most 5–7 g. clay is finely pounded with the required amount of stabilizing material and water added to make up to one litre. The stabilizing materials recommended and amounts are such as make the final mixture (*a*) 2 % in a potash soap, (*b*) 1 % in gum arabic, or (*c*) 0·25 % in gelatin. The mixture is allowed to stand for at least 24 hours, after which the liquid portion, which contains in suspension all the clay, is decanted, and flocculation caused by addition to (*a*) of 10 c.c. acetic acid, to (*b*) 15 c.c. HCl aq., while (*c*) is digested for some hours with pepsin. The method is applicable to rocks containing very little clay, e.g. some limestones. C. A. S.

Demolon (Albert) & Bastisse (E.). *Sur la dispersion des colloïdes argileux des sols et des sédiments.* Compt. Rend. Acad. Sci. Paris, 1934, vol. 199, pp. 675–677.

The resistance to flocculation of a clay suspension caused by addition of an alkali increases with concentration of hydroxyl to a maximum and then decreases. The presence of two cations, e.g. Na and K, increases the resistance and keeps it constant over a certain interval of *pH*. Accordingly, for extracting clay colloids the method proposed is: destroy organic matter with H_2O_2, wash with 0·1 *N*–KCl (100 c.c.

r 10–20 g.), agitate for one hour with 10 c.c. *N*-sodium citrate luted with 400 c.c. H_2O, and make up to 1000 c.c., extract clay by dimentation followed by flocculation with 0·02 *N*–HCl. In this ay the destructive action on the other constituents of the ordinarily ed means of removing carbonates, &c., is avoided. Examples are ven. C. A. S.

APPARENT (Jacques de). *Constitution et origine de la leverriérite.* Compt. Rend. Acad. Sci. Paris, 1934, vol. 198, pp. 669–671.

Leverrierite is an association of muscovite and kaolin in varying lative amounts, probably the result of decomposition of biotite nder humid conditions. The crystals of the two minerals are obably in definite orientation (epitaxy). C. A. S.

APPARENT (Jacques de). *La boehmite et le diaspore dans les fireclays de l'Ayrshire (Écosse).* Compt. Rend. Acad. Sci. Paris, 1934, vol. 199, pp. 1629–1631.

The aluminous constituent of these fireclays consists principally of ehmite (which forms the pisolites) with a small quantity of diaspore. e boehmite occurs mostly as minute crystals, though occasionally, drusy cavities, as crystals 0·06 mm. long; it is associated with olinite. Though of totally different origin these clays closely re- ble the bauxites of the Pyrenees (Ariège). [Cf. M.A. **5**–65.] C. A. S.

ROEL (J.) & CAILLÈRE (*Mlle.* S.). *L'analyse thermique différentielle des argiles à montmorillonite (bentonites).* Compt. Rend. Acad. Sci. Paris, 1933, vol. 197, pp. 774–777, 1 fig.

Temperature-time curves of the clays noted compared with similar rves of mixtures in known proportions of montmorillonite and olin (the presence of 3 % of which the method can detect) indicate at bentonite, otaylite, and amargosite are identical; and that con- lensite, steargillite, and beidellite are mixtures in varying propor- ons of montmorillonite and kaolin containing up to 30 % of the tter. Both montmorillonite and kaolin seem to be formed under milar physico-chemical conditions. C. A. S.

HWARZ (Robert) & TRAGESER (Georg). *Über die künstliche Umwandlung von Feldspat in Kaolin.* Zeits. Anorg. Chem., 1933, vol. 215, pp. 190–200, 2 figs.

Kaolin was prepared by the action of *N* or *N*/2 HCl at 320–330° C. orthoclase, anorthite, or leucite. Sulphuric, hydrofluoric, or

carbonic acids cannot replace the hydrochloric, and at temperatures from 180° to 250° C. no kaolin is formed, though the felspar is attacked and gelatinous silica produced. Kaolin itself is decomposed by hydrochloric acid at 220° C., but not at 320° C. The formation of kaolin in nature is therefore indirect, and not a simple substitution reaction. [Cf. M.A. **5**–255, 360, 361.] M. H. H.

Nagelschmidt (G.). *Röntgenographische Untersuchungen an Tonen. I. Die Röntgendiagramme einiger in Tonen vorkommender Mineralien. II. Der Mineralbestand des Mallisser Tones.* Zeits. Krist., 1934, vol. 87, pp. 120–145, 2 figs.

In order to facilitate the determination of the minerals composing clays, powder diagrams are given for the common constituents nacrite, dickite, kaolinite, halloysite, and montmorillonite. The advantage of the X-ray analysis of clays is illustrated by applying the method to a marine clay of Oligocene age from Malliss in Mecklenburg.

H. H.

Ross (Clarence S.) & Kerr (Paul F.). *Halloysite and allophane.* Prof. Paper U.S. Geol. Survey, 1934, no. 185–G, pp. 135–148, 2 pls., 3 text-figs.

Twelve analyses of halloysite (including 'indianaite', 'newtonite', and 'lithomarge') from various localities show a $SiO_2 : Al_2O_3$ ratio ranging from 206 : 100 to 165 : 100, the agreement with the usually accepted formula $H_2Al_2Si_2O_8$ being only approximate. Two types are distinguished: white and friable, and grey and porcellaneous. Most of the material is optically isotropic, but sometimes feebly birefringent ($< 0{\cdot}001$). n 1·546–1·559 for the analysed samples, 1·543–1·648 for others; [sp. gr. not given]. X-ray patterns with somewhat diffused bands show that the material is minutely crystalline, and with some relation to, but distinct from, kaolinite. The dehydration curve shows a gradual loss of water to 400–430° C. and a rapid loss to 500° C. Halloysite is a product of weathering, especially in association with sulphide ores, and it is often mixed with alunite. Allophane (including 'schrötterite') is truly amorphous and shows a wider range in composition, often containing admixed evansite (cf. viterbite, M.A. **3**–130) and other minerals. X-ray patterns show traces of diffused bands; n 1·472–1·512. The dehydration curve shows a gradual loss of water throughout. L. J. S.

OSHIKI (Bumpei). *Dickite in the rôseki deposits in Shôkôzan.* Proc. Imp. Acad. Tokyo, 1934, vol. 10, pp. 417–420, 2 figs.

— *Dickite from Shôkôzan, Japan (1).* Journ. Japanese Assoc. Min. Petr. Econ. Geol., 1934, vol. 12, pp. 107–115 (Japanese), 5 figs.

The 'rôseki' (wax-stone) of Shôkôzan, prov. Bingo, used in the ramic industry, represents an altered porphyrite, and is overlain alunite and traversed by veins of dickite. It consists of kaolin inerals and pyrophyllite, with diaspore [M.A. **5** 335] and associated rundum, topaz, &c. The dickite gave analysis SiO_2 46·15, Al_2O_3 3·93, MgO 0·36, CaO 0·26, ign. 14·19 = 99·89; $Bx_a = \gamma = b$, $: c = -7–9°$, ac 82°; α 1·561, β 1·563, γ 1·566. Optical data are ven for material at different stages of dehydration. L. J. S.

ONESS (Arthur P.) & WILLIAMS (Francis J.). *Dickite from Pennsylvania.* Amer. Min., 1935, vol. 20, pp. 462–466.

A white to yellowish glistening powder consisting of six-sided tes (up to 0·5 mm. across) and book-like groups came from Pine not colliery in Schuylkill Co. and from Colonial colliery at Natalie. xtinction on (010) 16°, α 1·560, β 1·562, γ 1·566, 2V fairly large, sitive sign. Analysis by G. A. Brady of pure material gave SiO_2 5·14, Al_2O_3 39·61, H_2O+ 13·91 = 99·66. X-ray measurements are ven. L. J. S.

ALL (Clayton G.). *Kaolinite in Illinois coal.* Econ. Geol., 1934, vol. 29, pp. 767–776, 2 figs.

White porcellaneous and minutely crystalline kaolinite occurs in inlets (up to 1 mm. wide) forming vertical partings in vitrain, and bands and cavities in fusain. It is of secondary origin and is ually associated with calcite. Analysis by O. W. Rees gave O_2 43·80, Al_2O_3 39·36, Fe_2O_3 0·82, MgO 0·16, CaO 1·17, ign. 5·40 = 100·71. A dehydration curve is given. The optical data 1·560, γ 1·565) and X-ray pattern agree with kaolinite. L. J. S.

ELÍŠEK (Josef). *Nový minerál moravský—kollyrit.* [New Moravian mineral—collyrite.] Příroda, Brno, 1932, vol. 25, p. 180.

— *Schrötterit, nový minerál moravský.* Ibid., 1933, vol. 26, pp. 157–160.

In the abandoned graphite mines at Bohuňov, western Moravia, nite, blue, and green schrötterite occurs as veinlets in collyrite nich fills calcite geodes. The schrötterite gave SiO_2 9·44, Al_2O_3 ·84, CaO 1·62, MgO 0·24, CO_2 1·08, SO_3 0·38, H_2O 42·50 = 100·10.

corresponding to $8Al_2O_3.3SiO_2.46H_2O$. The collyrite has the composition of 3 allophane + 2 gibbsite: its homogeneity was not examined. F. S.

Miscellaneous.

Michal (E.). *Aragonitové jeskyné v Hranickém krasu a nové objevy v nich.* [Aragonite-bearing caves in the Karst of Hranice and new finds in them.] Věda Přírodní, Praha, 1934, vol. 15, pp. 143–146, 169–171, 4 figs.

The cave of Teplice nad Bečvou in eastern Moravia is in Devonian limestone and from the ground there is an intense exhalation of carbon dioxide which is absorbed by the ground-water. In some parts of the cave the roof, walls, and stalactites are encrusted with tufts of acicular crystals of aragonite and paramorphs of calcite after aragonite. This aragonite contains $SrCO_3$ 3·56 %. Similar aragonite formations, also containing $SrCO_3$, occur in the cave of Demänová in northern Slovakia. F. S.

Kratochvíl (František). *Beryl z Meclova u Poběžovic.* [Beryl from Meclov near Poběžovice.] Rozpravy České Akad., 1934, vol. 44, no. 32, 8 pp.

Beryl is rather common as an accessory mineral in granite-pegmatites at Meclov (= Metzling) near Poběžovice (= Ronsperg) in Bohemia. The common type has sp. gr. 2·707, ω 1·581, ϵ 1·575, and the pale green variety sp. gr. 2·709, ω 1·580, ϵ 1·575. Analysis, using the guanidine carbonate method for the separation of Be and Al, gave: SiO_2 64·70, Al_2O_3 16·62, Fe_2O_3 1·58, FeO 1·11, BeO 13·43, MnO 0·01, MgO 0·02, CaO 0·21, Na_2O 0·67, K_2O 0·25, $H_2O(+110°)$ 1·67, $H_2O(-110°)$ 0·12 = 100·39. F. S.

Kašpar (Jan Václav). *Genese guanových minerálů z jeskyně Domice.* [Genesis of guano minerals from the Domica cave.] Věstník Státního Geol. Ústavu Československé Republiky, 1934, vol. 10, pp. 104–111, 3 figs. (Czech with French résumé.)

In the Domica cave, near Plešivec in southern Slovakia, the abundant stalagmites are corroded by solutions from bat guano giving rise to gypsum with intermixed collophanite, later brushite, and lastly earthy calcite. Partial analysis of the brushite gave P_2O_5 41·40, H_2O 25·62 and 26·47 %; four-fifths of the water is lost at 200–250° and one-fifth at about 400°, confirming the formula $CaHPO_4.2H_2O$. Sp. gr. of fresh crystals 2·244, after partial spontaneous dehydration

·253. The crystals are tabular on (010) and rhomb-shaped with ngles 37° and 143° or elongated. Acute positive bisectrix ⊥ (010), V 72° 30′, β 1·543. This is the first record of brushite from Czecho-ovakia. It is deposited from water with a constant temperature of 11°. The guano contains C 25·12, H 4·34, O 22·17 (diff.), N 7·43, 3·68, S 1·80, ash 35·46 %. F. S.

EKANINA (Josef). *Baryt od Kunštátu.* [Baryte from Kunštát, Moravia.] Příroda, Brno, 1934, vol. 27, pp. 86–88, 2 figs.

Colourless tabular crystals of baryte occur in cavities in pisolitic monite in Cretaceous strata and are accompanied by chalybite, alcite, aragonite, chalcosine, and malachite. Forms *cmabληχodlv frzRy* [Dana's letters]; sp. gr. 4·408, α 1·637, γ 1·649. F. S.

IAURITZ (Béla). *Aphrosiderit a Magas-Tátra gránitjából.—Aphrosiderit aus dem Granit der Hohen-Tatra.* Mat. Természettud. Értesítő, Budapest, 1935, vol. 53, pp. 238–246 (Hung.). p. 247 (Germ. résumé), 1 fig.

Analysis of aphrosiderite from the granite of the High-Tatra gave SiO_2 28·0, Al_2O_3 19·44, Fe_2O_3 6·10, FeO 23·32, MnO trace, MgO 10·02, aO 0·51, Na_2O 1·89, K_2O 0·97, H_2O+ 9·49, H_2O- 0·31 = 100·05, rresponding with daphnite 36·9, amesite 29·0, ferroantigorite 19·1, ntigorite 15·0 mol. %. D_4^{20} 2·924, n 1·635. V. Z.

OKODY (László). *A bindtbányai turmalin.—Turmalin von Bindtbánya.* Mat. Természettud. Értesítő, Budapest, 1934, vol. 50, pp. 650–658 (Hung.), p. 659 (Germ. résumé), 2 figs.

Black tourmaline from Bindtbánya, com. Szepes, shows the forms *r o* [Dana's letters]. The crystals are grown in chalybite (anal. I), nkerite (II), and quartz; analyses by G. Vavrinecz:

	CO_2.	FeO.	MnO.	MgO.	CaO.	$H_2O(-110°)$.	Insol.	Total.
I.	39·96	51·07	0·56	7·02	1·00	0·08	0·40	100·09
II.	43·36	20·38	0·28	8·92	27·01	0·16	0·12	100·23

V. Z.

OKODY (László). *A hessit szerkezete.—Über die Struktur des Hessit.* Mat. Természettud. Értesítő, Budapest, 1933, vol. 49, pp. 325–334 (Hung.), pp. 335–337 (Germ. résumé), 1 pl. [Cf. M.A. **5**–175, 310.]

Analysis of hessite from Botes, Transylvania, gave Ag 59·41, Au ·73, Te 35·97, Fe trace. V. Z.

Tokody (László) with Zimányi (Károly). *A pirit a{100}, o{111}, e{210}, s{321} formákból álló kristályainak lelőhelyei.—Fundorte der aus den Formen a{100}, o{111}, e{210}, s{321} bestehenden Kombinationen der Pyritkristalle.* Annales Musei Nationalis Hungarici, Budapest, 1934, vol. 28, pp. 113–146 (Hung. and Germ.). [Cf. M.A. **5**–133.]

Almost 2000 localities of pyrite crystals with the forms *a o e s* only, published up to the end of the year 1930, are listed alphabetically with the observers and bibliography. V. Z.

Reichert (Róbert). *A gömörmegyei Sajóháza és Rozsnyó szfaleritje.—Über den Sphalerit von Sajóháza und Rozsnyó (Kom. Gömör, Oberungarn).* Mat. Természettud. Értesítő, Budapest, 1934, vol. 50, pp. 660–667 (Hung.), p. 668 (Germ. résumé), 5 figs.

Rhombic-dodecahedral crystals of zinc-blende from Sajóháza show the forms *a d h o m*, σ, β, *n*, *p*, *s*, and an uncertain new form $(9\bar{7}2)$; also forms vicinal to $(3\bar{1}1)$–$(2\bar{1}1)$. Analysis by P. Szarvas gave S 32·50, Sb trace, Zn 65·58, Fe 1·46, Cd nil, insol. 0·19 = 99·73. Crystals from Rozsnyó show *a d o h* β, and $(8\bar{1}1)$. The crystals of both occurrences are of the 'Alston Moor' type. V. Z.

[Gerasimovsky (V.)] Герасимовский (В.). Рамзаит из центральных частей Хибинских тундр.—Gerassimovsky (W.). *Ramsayit aus den Zentralteilen der Chibina-Tundren.* Труды Ломоносов. Инст. Акад. Наук СССР (Trav. Inst. Lomonossov, Acad. Sci. URSS), 1935, no. 5 (Min.), pp. 131–147 (Russ. with Germ. summary), 2 figs.

Ramsayite occurring in alkali-pegmatites in the Khibinsky tundra [M.A. **3**–111] is of two types—zeolite and felspar types. Measurement of crystals of the zeolite type gave $a : b : c = 1{\cdot}6276 : 1 : 0{\cdot}6074$, with seventeen crystal-forms. The optical orientation is $\alpha = a$, $\beta = b$, $\gamma = c$; $\gamma - \alpha$ 0·072, 2V 38–40°, negative. L. J. S.

[Chirva (E. F.)] Чирва (Е. Ф.). К минералогии Березовского рудника на Урале пироморфит.—Čirva (E.). *Der Pyromorphit aus der Erzgrube von Beresowsk in Ural.* Труды Ломоносов. Инст. Акад. Наук СССР (Trav. Inst. Lomonossov, Acad. Sci. URSS), 1935, no. 5 (Min.), pp. 86–97 (Russ. with Germ. summary), 5 figs.

Crystals of pyromorphite from Beresovsk show the forms *c m a x y* [Dana's letters]; $a : c = 1 : 2726$. The following analyses show no

ation to the colour of the crystals: I, white; II, dark green; I, light green-yellow; IV, yellow passing into light green-blue and ht blue; V, light yellow-green. Sp. gr. of light yellow-white ystals 6·8537 %.

	P_2O_5.	As_2O_5.	Cl.	PbO.	Fe_2O_3.	Cr_2O_3.	CuO.	Total.
II.	15·45	—	2·89	81·63	—	—	—	99·97
I.	15·81	—	2·45	81·22	0·59	trace	—	100·07
II.	15·57	—	2·45	81·14	0·58	0·15	—	99·89
V.	15·56	—	2·75	81·34	—	—	trace	99·65
V.	15·60	0·82	2·64	81·05	—	—	—	100·11

L. J. S.

ıkyul (E. O.)] Искюль (E. O.). О нонтроните из Андреасберга в Гарце.—Iskül (H.). *Über den Nontronit von St. Andreasberg am Harz.* Труды Ломоносов. Инст. Акад. Наук СССР (Trav. Inst. Lomonossov, Acad. Sci. URSS), 1935, no. 5 (Min.), pp. 149–156 (Russ. with Germ. summary), 1 fig.

The small grains or spherulites of nontronite consist of fine fibres th γ' 1·605 parallel to the elongation and α' 1·585. Analysis O_2 40·66, Al_2O_3 7·62, Fe_2O_3 26·60, FeO 0·15, MgO 0·24, CaO 3·44, O 0·12, K_2O 0·16, SO_3 0·06, H_2O 21·07 = 100·12, gives

$$R_2O_3.2{\cdot}80SiO_2.4{\cdot}48H_2O.$$

L. J. S.

ıLÈRE (Simonne). *Sur les caractères spécifiques de la bowlingite.* Compt. Rend. Acad. Sci. Paris, 1935, vol. 200, pp. 1483–1485.

Analyses of bowlingite from Blackburn, Scotland (I); from Catkin ll, Glasgow (after removal of $CaCO_3$) (II); of saponite from Catkin ll (III); and of diabantite from Bergen Hill (IV), are as follows:

	SiO_2.	TiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	MgO.	CaO.	$H_2O(+)$.	$H_2O(-)$.	Total.
.	39·37	0·07	8·11	5·94	7·36	21·47	0·69	9·23	7·69	99·93
.	41·66	0·32	9·55	5·69	4·20	20·14	0·29	8·08	9·79	99·72
.	40·04	0·41	6·76	9·29	2·38	19·13	2·27	7·84	11·91	100·03
	38·49	—	5·05	10·59	3·23	19·45	2·83	6·43	13·52	99·59

e formula $5SiO_2.(Al,Fe)_2O_3.4{\cdot}5–5(Fe,Ca,Mg)O.3{\cdot}5–4H_2O$ applic- le to I, II, III, the thermal analysis curves and X-ray diagrams of ich are identical. Quantitative dehydration of I shows that most of H_2O is lost at 615° and all at 715°, but the structure remains that the original mineral, this being only changed at a higher tempera- re (1100–1200°) indicating partial transformation into enstatite d magnetite. III behaves quite and IV very nearly similarly. wlingite is therefore only a fibrous variety of saponite. C. A. S.

Longchambon (Henri). *Sur la formule chimique et la constitution de la sépiolite d'Ampandrandava.* Compt. Rend. Acad. Sci. Paris, 1935, vol. 200, pp. 1607–1609.

From previous results [M.A. **5**–334; **6**–62, 63] it is concluded that the mineral as found, sepiolite I, consists of continuous Si-O chains (thus explaining the fibrous structure), united transversely by magnesium, hydrogen, and hydroxyl ions, the theoretical formula being $(Mg,H_2)_3Si_4O_{11}.1H_2O.nH_2O$, and the average composition $Mg_{2\cdot58}H_{0\cdot84}Si_4O_{11}.nH_2O$, where the nH_2O ($n = 0\cdot7 - 3\cdot7$) represents the zeolitic water. On moderate heating it passes into sepiolite II with loss of the water. Sepiolite II is, however, still able to retain about $0\cdot4H_2O$ per molecule, the chains remaining intact but contracted in cross-section. On further heating, the chains are destroyed with loss of any remaining water. Sepiolite is accordingly placed in the amphibole group. C. A. S.

Longchambon (Henri) & Migeon (Georges). *Sur la définition des sépiolites.* Compt. Rend. Acad. Sci. Paris, 1935, vol. 200, pp. 1946–1949.

A connected summary of results already published [M.A. **6**–62, 63]. C. A. S.

Pehrman (G.). *Die Einwirkung der Clerici'schen Lösung auf Gips.* Zentr. Min.,[1] Abt. A, 1935, pp. 54–55.

In Clerici's solution (thallium formate and malonate, M.A. **2**–487) gypsum becomes cloudy and increases in density, and after 42 hours sinks in the liquid ($d > 4$). This is due to the formation of thallium sulphate. L. J. S.

Machatschki (F.). *Kristallisierter Melanterit von Pfaffenreuth, Bayern.* Zentr. Min., Abt. A, 1935, pp. 53–54, 1 fig.

Small (1 mm.) clear green crystals of melanterite were found with halotrichite in an old graphite mine. They are octahedral in habit owing to the equal and predominant development of $m(110)$, $c(001)$, and $\rho(\bar{1}01)$. Other forms present are (011), (100), $(\bar{2}01)$, the last two new for melanterite. Measurements gave $a : b : c = 1\cdot180 : 1 : 1\cdot534$, $\beta = 75° 37'$. L. J. S.

[1] With the first number for 1935 the title of the Centralblatt has been changed to Zentralblatt für Mineralogie, Geologie und Paläontologie.

ITTGENBACH (H.). *Wulfénite et baddeleyite du Congo belge.* Ann. Soc. Géol. Belgique, Publ. Congo Belge, 1935, vol. 58, pp. c 68–c 69, 1 fig.

Small crystals of wulfenite on torbernite from Kasolo, Katanga, ow a square prism (410) terminated by *n* or *nc* [Dana's letters]. Iddeleyite as brown prisms, *m* (110) frequently terminated by 021), in concentrates of gold washings at Nedi, Kilo; sp. gr. 0–5·81. L. J. S.

IBEL (René van). *Sur quelques minerais tantalo-columbifères du Kivu.* Ann. Soc. Géol. Belgique, Publ. Congo Belge, 1935, vol. 58, pp. c 38–c 41.

Small water-worn fragments of prisms from gold-washings are ntified as tantalo-columbite, samarskite (*d* 5·7, *n* 2·19), and euxe- e (*d* 4·85, *n* 2·205–2·214). L. J. S.

OKE (S. R. B.) & DOAN (Donald J.). *The mineragraphy and X-ray analysis of stainierite from the Swansea mine, Goodsprings, Nevada.* Amer. Min., 1935, vol. 20, pp. 274–280, 5 figs.

A dull black cobalt mineral occurs finely disseminated in calcite dolomite, the crude ore containing 1·23% cobalt. Polished tions show both anisotropic and isotropic portions (the latter bably cryptocrystalline), and both give the same X-ray pattern stainierite, $Co_2O_3.H_2O$ [M.A. **4**–248, 347]. L. J. S.

IDOLICO (Francesco). *Cristalli di cinabro del Monte Amiata e di calcosina dell'Impruneta (Toscana).* Periodico Min. Roma, 1935, vol. 6, pp. 25–30, 1 pl.

Crystals of cinnabar from Monte Amiata show the rhombohedron (03$\bar{3}$4) as the predominating form, with small *e* (30$\bar{3}$8), Φ (30$\bar{3}$2), 11$\bar{2}$0), *m* (10$\bar{1}$0), Δ (12$\bar{3}$0) ?, and *D* (21$\bar{3}$7) ?, Φ and Δ being new ms [$a : c = 1 : 1{\cdot}14526$]. Crystals of chalcosine from Impruneta ow *a e g*, *i* (052), *m p v z* [Dana's letters]. L. J. S.

NOGLIO (Massimo). *Ricerche sulla nesquehonite delle miniere di Cogne in Val d'Aosta.* Periodico Min. Roma, 1935, vol. 6, pp. 1–17, 2 pls.

This occurs with lansfordite as tufts of prismatic crystals on ser- ntine [M.A. **5**–431]. Analysis gave MgO 29·09, CO_2 31·63, H_2O ·21 = 99·93, agreeing with $MgCO_3.3H_2O$. Measurement of crystals ve $a : b : c = 0{\cdot}6444 : 1 : 0{\cdot}4515$; forms *c b m d*. Sp. gr. 1·842. Optic ial plane (001), $Bx_a \perp (100)$; α 1·417, β 1·503, γ 1·527, 2V 53° 3′,

negative. X-ray measurements give a unit cell a 7·68, b 11·93, c 5·39 containing four molecules; space-group V_h^1. L. J. S.

Stearn (Noel H.). *Stibnite in quartz.* Amer. Min., 1935, vol. 20, pp. 59–62, 1 fig.

Threads of stibnite enclosed in clear crystals of quartz are described from Golden Spike gold mine, Pershing Co., Nevada, and from the Parnell Hill and Gap Ridge mercury mines, Pike Co., Arkansas. Cinnabar is also enclosed in the quartz crystals from the latter locality. L. J. S.

Tarr (W. A.). *The linnaeite group of cobalt-nickel-iron-copper sulfides.* Amer. Min., 1935, vol. 20, pp. 69–80, 4 figs.

Thirty-seven published analyses of linnæite, carrollite (including sychnodymite), siegenite, violarite, and polydymite are tabulated. They agree with the general formula $R''R'''_2S_4$, where R'' = Co, Ni, Fe, Cu, and R''' = Co, Ni, Fe, so conforming with the spinel type of structure [M.A. **3**–339, 426]. With decrease of Co + Cu through the series there is a corresponding increase of Ni + Fe. L. J. S.

Rogers (Austin F.). *The chemical formula and crystal system of alleghanyite.* Amer. Min., 1935, vol. 20, pp. 25–35, 13 figs.

A re-examination of alleghanyite from Bald Knob, Alleghany Co., North Carolina [M.A. **5**–50], shows that the formula is $5MnO.2SiO_2.H_2O$ or $2Mn_2SiO_4.Mn(OH,F)_2$ (not $5MnO.2SiO_2$), that it is monoclinic (not orthorhombic), and that it is isomorphous with chondrodite. A new analysis by R. B. Ellestad gave SiO_2 22·75, TiO_2 0·15, Al_2O_3 0·75, Fe_2O_3 0·73, MnO 67·85, MgO 0·71, CaO 1·34, H_2O 2·56, F 0·30, CO_2 1·92, S 0·11, from which small amounts of galaxite, calcite, and alabandite are deducted. The crystals show lamellar twinning on (001), and occasionally contact twins on (105) and (305). Optic axial plane $\perp$ (010), $a : a = -35°$, $c : \beta = -35°$. L. J. S.

McKnight (Edwin T.). *Occurrence of enargite and wulfenite in ore deposits of northern Arkansas.* Econ. Geol., 1935, vol. 30, pp. 61–66, 2 figs.

Enargite as small crystals ($a\ m\ c\ b\ s$) was found with blende, &c., in the Governor Eagle mine, Marion Co. Wulfenite and cerussite coat lumps of galena found in residual clay from the weathering of dolomite in Shiras mine, Baxter Co. These are the first arsenic and molybdenum minerals to be noticed in the zinc-lead ores of the Mississippi valley. L. J. S.

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